Part I

General Approach for DOE Seismic Evaluation Procedure

1. INTRODUCTION

1.1 PURPOSE OF THE DOE SEISMIC EVALUATION PROCEDURE

U.S. Department of Energy (DOE) facilities need to have adequate measures for protection of public health and safety, for on-site worker life safety, for protection of the environment, and for investment protection in the event of natural phenomena hazards, specifically earthquakes. Due to the evolutionary nature of design and operating requirements as well as developments in engineering technology, DOE facilities embody a broad spectrum of design features for earthquake resistance. These features depend on factors such as vintage of the facility design and construction and hardware supplier practices at the time of design and construction. The earliest-vintage facilities often have the least design consideration for seismic and potentially exhibit the greatest difference between their design basis and what DOE requires today for seismic design criteria for new facilities.

Seismic evaluations of essential systems and equipment at many DOE facilities will be conducted over the next several years. For many of these systems and components, few, if any, seismic requirements applied to the original design, procurement, installation, and maintenance process and therefore, the evaluation of the seismic adequacy of existing systems and components presents a difficult challenge. The purpose of this Seismic Evaluation Procedure is to summarize a technical approach and provide generic procedures and documentation requirements that can be used at DOE facilities to evaluate the seismic adequacy of mechanical and electrical equipment.

This procedure is meant to comply with DOE Policy, Orders, and Standards as discussed in Section 1.2. The scope of equipment covered in this procedure includes active mechanical and electrical equipment such as batteries on racks, motor control centers, switchgear, distribution panels, valves, pumps, HVAC equipment, engine generators, and motor generators. In addition, this generic procedure includes guidelines for evaluating the seismic adequacy of tanks, heat exchangers, cable and conduit raceway systems, piping systems, HVAC ducts, architectural features and components, and relays.

The Seismic Evaluation Procedure is intended to provide DOE facility managers, safety professionals, and engineers with a practical procedure for evaluating the seismic adequacy of equipment and distribution systems. Often the approach used to review the seismic capacity of equipment is to conduct sophisticated evaluations that can be very time consuming, complex, and costly. Much of the available funding is spent on analysis rather than on the real objective of increasing the seismic capacity of equipment and distribution systems. This procedure is designed to be an extremely cost-effective method of enhancing the seismic safety of facilities and reducing the potential for major economic loss that can result from equipment and systems damaged or destroyed by an earthquake.

The following sections provide the background for the development of the DOE Seismic Evaluation Procedure. First, DOE Orders and Standards that address natural phenomena hazards are discussed since a purpose of the DOE Seismic Evaluation Procedure is to provide a procedure that satisfies the requirements of these Orders and their supporting standards. Second, a methodology that was developed for older nuclear power plants to satisfy safety issues raised in the late 1970s is discussed. This methodology or procedure is based on seismic experience data and screening evaluations. The nuclear power industry concluded that the methodology was the most viable option to resolve safety issues as compared with testing or analysis. Testing or analysis were often not viable due to problems of removal, decontamination, shipment of equipment for testing, access, and potential damage from in-situ testing. Next, the extension to DOE facilities of the procedure developed for nuclear power plants is discussed. Applications at nuclear power plants and DOE facilities have demonstrated that a seismic evaluation using the methodology based on experience data is the only viable option for many systems and components. Finally, the license which regulates the use of background material for the DOE Seismic Evaluation Procedure is discussed.

1.2 DOE ORDERS AND STANDARDS

The DOE Seismic Evaluation Procedure is intended to comply with DOE Policy, Orders, and Standards on natural hazards mitigation which allow for the seismic evaluation of systems and components by analysis, testing, or the use of earthquake experience data. These include DOE Order 420.1, "Facility Safety" (Ref. 5), and its Implementation Guide; a rule currently under development; and supporting Standards. The two supporting Standards most relevant to this procedure are DOE-STD-1020, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities" (Ref. 6) (see Section 2.4.1 of DOE-STD-1020) and DOE-STD-1021, "Natural Phenomena Hazard Performance Categorization Guidelines for Structure, Systems, and Components" (Ref. 7). DOE Order 420.1 is a replacement order for DOE Order 5480.28, "Natural Phenomena Hazards Mitigation" (Ref. 8).

DOE Orders and Standards for natural phenomena hazards mitigation are closely linked to those for safety analysis. DOE Order 5480.23 (Ref. 9) requires that safety analyses be performed that develop and evaluate the adequacy of a DOE nuclear facility's safety basis and that the analyses be documented in a Safety Analysis Report (SAR). To assist in preparing a SAR, DOE-STD-1027 (Ref. 10) and DOE-STD-3009 (Ref. 11) provide guidance on hazard categorization and SAR implementation, respectively. Using a graded approach unique to DOE, systems and components are subjected to different seismic design and evaluation criteria that correspond to safety system and facility hazard classifications. The graded approach and wide diversity of DOE facilities' functions and designs require that the methodology developed for equipment in commercial nuclear power plants, as discussed in the next section, be modified for use at DOE facilities.

1.3 USE OF SEISMIC EXPERIENCE DATA IN NUCLEAR POWER PLANTS

1.3.1 Background[1]

The requirements for seismic design of nuclear power plants from 1960 to the present have evolved from the application of commercial building codes, which use a static load coefficient approach applied primarily to major building structures, to more sophisticated methods today. Current seismic design requirements for new nuclear power plants consist of detailed specifications that include dynamic analyses or testing of safety-related structures, equipment, instrumentation, controls, and their associated distribution systems, such as piping, cable trays, conduit, and ducts. In the late 1970s, the U.S. Nuclear Regulatory Commission (NRC) expressed the concern that nuclear equipment seismically qualified to standards preceding IEEE-344-1975 (Ref. 12) might not provide sufficient assurance of seismic adequacy. This concern was reinforced through field inspections of older-vintage nuclear power plants where equipment was found to lack adequate anchorage.

The NRC initiated Unresolved Safety Issue (USI) A-46, "Seismic Qualification of Equipment in Operating Plants" (Ref. 13) in December of 1980, to address the concern that a number of older operating nuclear power plants contained equipment which may not have been qualified to meet newer, more rigorous seismic design criteria. Much of the equipment in these operating plants was installed when design requirements, seismic analyses, and documentation were less formal than the rigorous practices currently being used to build and license nuclear power plants. However, it was realized that it would not be practical or cost-effective to develop the documentation for seismic

[1] Based on Section 1.2 of SQUG GIP (Ref. 1)

qualification or requalification of safety-related equipment using procedures applicable to modern plants. Therefore, the objective of USI A-46 was to develop alternative methods and acceptance criteria that could be used to verify the seismic adequacy of essential mechanical and electrical equipment in operating nuclear power plants. The NRC pursued several options for the resolution of USI A-46, including use of shake table testing, in-situ testing, deterministic and probabilistic analytical methods, and seismic experience data. Most options proved not to be viable because of the unavailability of older model components for testing, the high costs of component replacements, and complications of testing radiologically contaminated equipment. The NRC concluded that the use of experience data could provide a reasonable alternative for resolution of USI A-46.

In early 1982, the Seismic Qualification Utility Group (SQUG) was formed for the purpose of collecting seismic experience data as a cost-effective means of verifying the seismic adequacy of equipment in operating plants. One source of experience data was the numerous non-nuclear power plants and industrial facilities which had experienced major earthquakes. These facilities contained industrial grade equipment similar to that used in nuclear power plants. Another source of seismic experience data was shake table tests that had been performed since the mid 1970's to qualify safety-related equipment for licensing of nuclear plants. To use these sources of seismic experience data, SQUG and the Electric Power Research Institute (EPRI) collected and organized this information and developed guidelines and criteria for its use. The guidelines and criteria provided the generic means for applying experience data to verify the seismic adequacy of mechanical and electrical equipment required to be used in a nuclear power plant during and following a safe shutdown earthquake (SSE). According to 10CFR100 Appendix A (Ref. 14), the SSE is defined as the earthquake which is based upon the maximum earthquake potential considering both regional and local geology, seismology, and local subsurface materials. For nuclear power plants, the SSE is also referred to as the Design Basis Earthquake. The ground motion at the nuclear facility associated with the SSE is used for the design of equipment, structures, and systems necessary for: the integrity of the reactor coolant pressure boundary, the capability to shut down and maintain the reactor in a safe shutdown condition, and the capability to prevent or mitigate potential offsite exposures.

1.3.2 Approach

The approach developed by SQUG and EPRI for verifying the seismic adequacy of mechanical and electrical equipment is consistent with the intent of NRC Generic Letter (GL) 87-02, "Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46" (Ref. 15), NUREG-1030 (Ref. 16), and NUREG-1211 (Ref. 17). The approach is also consistent with the EPRI Seismic Margins Assessment Program described in Reference 18. NRC approval of the approach was based on research done at several DOE national laboratories and on extensive independent review by the Senior Seismic Review and Advisory Panel (SSRAP). The summary of the SSRAP review is contained in Reference 19. In 1987, NRC GL 87-02 required utilities to respond to USI A-46, and encouraged participation in generic resolution by using the SQUG approach, documented in the Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment (Ref. 1). NRC accepted the SQUG GIP (also referred to as the Industry GIP) with a generic safety evaluation report (Ref. 2). There were a few exceptions that have since been resolved and are being incorporated into Revision 3 of the SQUG GIP (Ref. 4). The SQUG GIP consists of four sets of criteria:

1) the experience-based capacity spectrum must bound the plant seismic demand spectrum,
2) the equipment item must be reviewed against certain inclusion rules and caveats,
3) the component anchorage must be evaluated, and
4) any potentially significant seismic systems interaction concerns that may adversely affect component safe shutdown function must be addressed.

These SQUG criteria are in the form of screening evaluation guidelines. Items not passing the screen, called outliers, are not necessarily inadequate, but other seismic engineering methods must be used to further evaluate these items.

The screening evaluation adopted in the SQUG GIP is generally a conservative and rapid appraisal process that is used during a facility walkdown to verify acceptability or identify outliers by review of key physical attributes. A model of the screening evaluation process is shown in Figure 1.3-1. Items passing the screen are verified as acceptable and may be documented as such, or can be selected for a bounding sample analysis to validate the evaluation results. Items not passing the screen are not verified and are formally designated as outliers, which must be subject to more detailed review or upgrade before being accepted. The SQUG GIP screening evaluation process is performed primarily during in-plant walkdowns and for a limited set of equipment, or Safe Shutdown Equipment List (SSEL), required to bring a plant to hot shutdown and maintain it there for 72 hours. Prior to a screening evaluation, a systems review is conducted to assess the minimal and prioritized scope of equipment for the evaluation.

Results of the work in compiling earthquake experience data by SQUG found the following: (1) conventional power plant and industrial facility equipment are generally similar to that found in older, operating nuclear power plants and, (2) equipment, when properly anchored, will generally perform well in earthquakes at levels of shaking in excess of the SSE for many nuclear power plants. SQUG, EPRI, and SSRAP developed the caveats and inclusion rules that help to ensure functionality and structural integrity of equipment when using the experience-based methodology. Caveat and inclusion rules determine whether or not an item of equipment is sufficiently similar to data from past earthquake or testing experience. The SQUG program is considered by most, including the NRC and all of the SQUG utility members, to be a major engineering breakthrough and an overall success. Important methods utilized by SQUG include: utilization of screening criteria implemented during walkdowns that is coupled with review team engineering training, screening criteria primarily based on natural phenomena experience data that is supplemented with test and analysis, programmatic direction given by facility management and engineering, technical review and advice provided by an independent panel of industry experts, and establishing priority listing of systems and components based on systems analysis.

An important element of the SQUG GIP is its application by the use of specially trained and experienced seismic review teams who must exercise considerable judgment while performing the in-plant screening evaluations. Besides establishing strict qualification requirements for review team engineers, SQUG and EPRI provide a training course in the use of the implementation guidelines and procedures.

The EPRI / SQUG seismic evaluation methodology based on experience data has become a key element in the ongoing earthquake evaluations for commercial nuclear power plants. The experience-based evaluation methods address most plant components needed for safe shutdown in the event of a SSE. These components include 20 classes of electrical and mechanical equipment, cable trays and conduit systems, relays, anchorage, tanks and heat exchangers. For each type of component, the seismic evaluation methodology provides experience data that documents the performance of systems and components that have been subjected to earthquake motion. The data includes components in commercial and industrial facilities that were in the strong motion regions of major earthquakes. SQUG and EPRI have developed a seismic experience data base that includes the response of systems and components in about 100 (typically non-reactor) facilities located in areas of strong ground motion from 20 earthquakes. The earthquakes have Richter magnitudes in the range of 5.2 to 8.1, have peak ground accelerations from 0.10g to 0.85g, and have about 3 to 50 second durations. Soil conditions, building structure types, and location of equipment vary considerably within the data base.

The facilities surveyed and documented contain a large number of mechanical and electrical equipment, and control and distribution systems that are identical or very similar to those found in nuclear power plants. Information sources consist of interviews with facility management and operating personnel, walkdown inspections of facilities, photographs and performance data records of systems and components, facility operating logs, and the facility's inspection reports. Design criteria and specifications, component data books, and design drawings are additional sources of information. There is diversity in equipment design, size, configuration, age, application, operating conditions, manufacturer, and quality of construction and maintenance. The earthquake experience data are useful for determining common sources of seismic damage or adverse effects of equipment and facilities, thresholds of seismic motion corresponding to various types of seismic performance, and standards in equipment construction and installation to ensure the ability to withstand anticipated seismic loads.

As an expansion of the earthquake experience data, EPRI and SQUG also collected data on shake-table qualification tests from utilities, manufacturers, and test laboratories. Results were compiled from about 300 shake table tests of equipment components, covering 15 generic classes of equipment. The objective was to compile the information by class, and to obtain generic insights, if any, that could be used to assist utilities in evaluating these equipment classes in their plants. These generic equipment ruggedness data represent substantially higher levels of seismic motion than the earthquake experience data, but in most cases, are applicable to a narrower range of equipment parameters. EPRI and SQUG also obtained available electro-mechanical relay chatter shake table tests and performed additional tests for other relays. The relay test experience data base provides capacities for about 150 specific models of relays.

Another important element of seismic experience data is information on the anchor bolts that are commonly used to attach systems and components to the supporting building structure. EPRI and SQUG have summarized capacity information for expansion anchor bolts, covering about 1200 ultimate capacity tension and shear tests. Capacity data have also been compiled for other anchor types including welded attachments, cast-in-place bolts and headed studs, grouted-in-place anchors, and cast-in-place J-hooks.

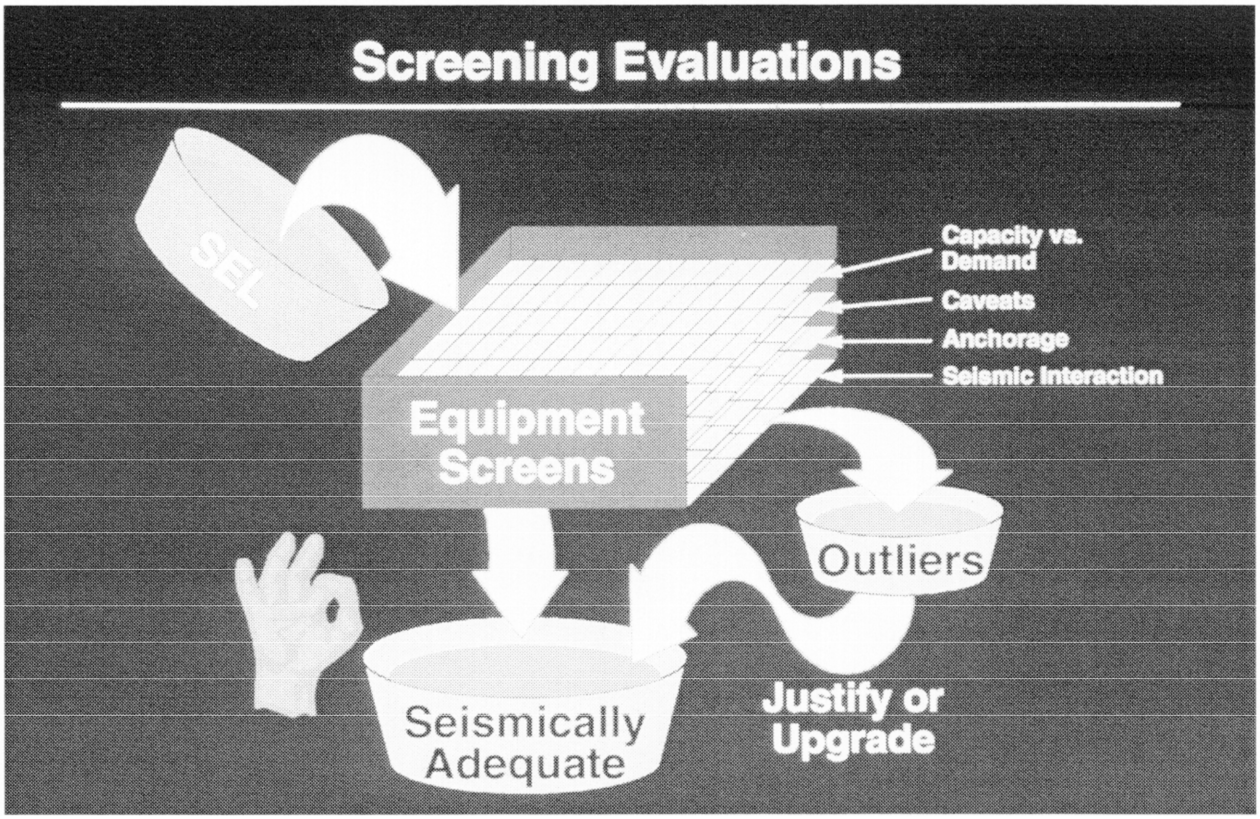

Figure 1.3-1 **The DOE Seismic Evaluation Procedure contains the screening evaluation approach. The process begins with the development of the Seismic Equipment List (SEL).**

1.4 USE OF SEISMIC EXPERIENCE DATA IN DOE FACILITIES

1.4.1 DOE Existing Facilities Program

A DOE Existing Facilities Program was implemented for the development of seismic evaluation guidelines for systems and components at existing facilities. A Program Plan (Ref. 20) for the Existing Facilities Program maximizes the use of past experience in conjunction with a walkdown screening evaluation process in order to meet the policy of applicable DOE Orders and Standards. The process of evaluating existing DOE facilities for the effects of natural phenomena hazards was patterned after the SQUG program for commercial nuclear power plants, which is discussed in Section 1.3. As discussed in Section 1.5, the SQUG and EPRI reference documents, which provide the basis for the use of experience data, are being used by DOE through a special agreement between Lawrence Livermore National Laboratory (LLNL) and EPRI. The use of seismic experience data, specifically the EPRI / SQUG data, for DOE seismic evaluations was recommended in a position paper (Ref. 21) authored by personnel from many DOE facilities. In addition, a letter (Ref. 22) from Robert Kennedy, a member of SSRAP who has also been involved in the technical review of the DOE Seismic Evaluation Procedure, endorses the use of experience-based seismic evaluations for equipment in existing DOE facilities.

A Walkthrough Screening Evaluation Field Guide (Ref. 23) was developed to assist in rapidly identifying major deficiencies at existing DOE facilities. The document was developed based on walkdown experience at nuclear power plants, revised after applying it to walkdowns at selected DOE facilities, and used as an interim methodology before the DOE Seismic Evaluation Procedure was fully developed. The purpose of the Field Guide was to direct walkthrough screening evaluations of DOE facilities in the technical area involving potential hazards caused by natural phenomena. Using the Field Guide, the walkthrough screening evaluation is a facility appraisal of key physical attributes. Items that pass the screen are considered to possess no obvious deficiencies and documented evaluation may be deferred. Items not passing the screen may be of concern such that detailed review or upgrade may be appropriate for these cases depending on potential risk. The methodology in the DOE Seismic Evaluation Procedure is a more thorough extension of the concepts developed in the Field Guide.

1.4.2 Development and Technical Review of the DOE Seismic Evaluation Procedure

The DOE Seismic Evaluation Procedure is based on Part II of Revision 2 of the SQUG GIP. Since DOE facilities, objectives, and criteria are different from those for commercial nuclear power plants, the DOE Seismic Evaluation Procedure has been enhanced with information from the SEP-6 (Ref. 3) developed for the Savannah River Site (SRS) and from several DOE guidance documents. In addition, DOE-specific requirements and guidance and equipment classes not contained in the SQUG GIP, such as piping systems and unreinforced masonry walls, have been included in the DOE Seismic Evaluation Procedure. The DOE classes of equipment are contained in Chapter 10 and their development and pedigree are discussed in Section 2.1.3.4.4. Nuclear power plant and NRC-specific requirements from the SQUG GIP have been removed and an attempt is made to reduce some of the repetition in the SQUG GIP and make the procedure less cumbersome to use. Additional information on the differences of the DOE Seismic Evaluation Procedure and the SQUG GIP is contained in the Foreword.

Since DOE facilities are not structurally equivalent to nuclear power plants, which are typically stiff, shear wall structures, the approach in the SQUG GIP for comparing seismic capacity with seismic demand has been modified for DOE usage. An assessment (Ref. 24) was done of the performance goals that are achieved when seismic experience-based screening evaluation methods are used. In contrast to the SQUG deterministic criteria, DOE facilities are required to demonstrate the ability to achieve probabilistic performance goals. As discussed in Chapter 5, experience data factors are used to scale in-structure response spectra that are derived from the Design Basis Earthquake (DBE) for a facility. The scaled in-structure spectra, or the Seismic Demand Spectrum (SDS), are compared with experience-based capacity spectra.

DOE facility management and operations personnel have played an important role in the development and review of the approach implemented by the DOE Seismic Evaluation Procedure. A Steering Group of selected individuals from the DOE operating contractors have ensured that appropriate priorities were established from the facility operations perspective. The Steering Group is a five-member panel, which is nominated by DOE and its consultants, and is considered a key element to the success of the overall approach presented in the DOE Seismic Evaluation Procedure. The Steering Group has the primary responsibility of reviewing the DOE Seismic Evaluation Procedure in conjunction with a check of technical content and potential impact to a site from a cost, schedule, or operations standpoint. In addition, the Steering Group played a decisive role in the selection of the technology transfer mechanisms for the facility evaluations. Members of the Steering Group and appropriate support personnel have met regularly to discuss and decide on issues affecting the procedures. Examples of issues for which the Steering Group provided a decisive role toward final outcome include implementation procedures, documentation requirements, scope of detailed system and component evaluation tools, peer review requirements, anticipated level of effort for the reviews, and system prioritization guidelines for a facility. The Steering Group also formed a technical review committee to conduct an independent and thorough technical review of the information in the DOE Seismic Evaluation Procedure. The review committee was modeled after SSRAP which was used for the technical review of the SQUG GIP. Members of the review committee were Robert Budnitz, Robert Kennedy, and Loring Wyllie. Since Robert Kennedy participated in the development of Section 10.5.1, he was not an independent technical reviewer of that section.

Two preliminary drafts of the DOE Seismic Evaluation Program were prepared in January and June of 1995. The June 1995 Draft was technically reviewed by staff at DOE, personnel at DOE sites, and several consultants. Based on the review comments, a second Draft of the DOE Seismic Evaluation Procedure (Ref. 25) was published in September 1995 for review by the DOE, personnel from DOE sites, technical consultants, and attendees of DOE training courses on the EPRI / SQUG methodology. A Final Draft of the Procedure (Ref. 26) was published in November 1996 and it incorporated detailed review comments from the technical reviews of the September 1995 Draft of the Procedure. Following a technical review of the Final Draft, minor modifications were made to the Procedure, except for Section 10.5.1 on Unreinforced Masonry (URM) Walls. Robert Murray and Robert Kennedy extensively revised Section 10.5.1 to incorporate review comments and enhance the methodology in that section.

The technical reviews of the DOE Seismic Evaluation Procedure, which are listed in Table 1.4-1, have provided information for improving portions of the procedure and for emphasizing the appropriateness of using experience data for evaluating the seismic adequacy of equipment. The primary charter of the technical reviews was to independently determine the adequacy of the technical content of the screening evaluation guidelines, including the safety margins that result from implementation of the criteria. For sections of the DOE Seismic Evaluation Procedure that are identical or technically equivalent to corresponding sections in the SQUG GIP, the technical aspects of these sections were reviewed as part of the SSRAP and other reviews of the SQUG GIP as listed in Table 1.4-1. While the technical reviews of the DOE Seismic Evaluation Procedure were modeled after SSRAP, the technical reviews of the DOE Procedure did not involve as many reviewers as the review of the SQUG GIP and did not require formalized consensus building between the DOE and the technical reviewers. Technical reviewers of the DOE Seismic Evaluation Procedure, especially the technical consultants, have extensive experience in the evaluation of the seismic adequacy of equipment and were members of SSRAP or were involved with the development of the SQUG GIP. The emphasis of the technical review of the DOE Seismic

Evaluation Procedure was the sections of the procedure that are different from the SQUG GIP and there was special focus on Chapter 10, which contains classes of equipment that are not in the SQUG GIP. The key technical consultants reviewing the DOE procedure included Robert Budnitz, Robert Kennedy, and Loring Wyllie as members of the technical review committee. These review efforts were supplemented by reviews by DOE staff and personnel at DOE sites, especially SRS and LLNL, and several engineers from EQE International who had extensive experience with the SQUG GIP.

In addition to the overall review of the DOE Seismic Evaluation Procedure, several sections of the procedure, as listed in Table 1.4-1, received specialized or additional review and in some cases, information about the reviews is referenced. The methodology in Reference 24, which is the basis for Chapter 5, was reviewed by John Reed and Section 10.1.1 on piping was reviewed by Ed Wais (Ref. 27). Section 10.4.1 on HVAC ducts is based on a procedure used at SRS (Ref. 28) and this procedure has been subjected to independent technical review by DOE staff, personnel at DOE sites, and technical consultants. Section 10.3.1 on underground tanks and Section 10.1.2 on underground piping are based on a DOE report that was developed at Brookhaven National Laboratory (Ref. 29) and has been reviewed by DOE staff, personnel at DOE sites, technical consultants, and the American Society of Civil Engineers, Dynamic Analysis of Nuclear Structures Committee. An independent review of Section 10.5.1 on unreinforced masonry walls was performed at the Lawrence Livermore National Laboratory.

Table 1.4-1 Technical Reviews of DOE Seismic Evaluation Procedure

Chapter or Section of the DOE Seismic Evaluation Procedure	Technical Aspects Reviewed as Part of SQUG GIP	Reviewed by Technical Consultants for the DOE	Specialized Review for the DOE
Chapter 1		X	
Chapter 2		X	
Chapter 3		X	
Chapter 4		X	
Chapter 5		X	X
Chapter 6	X	X	
Chapter 7	X	X	
Chapter 8	X	X	
Chapter 9	X	X	
Section 10.1.1		X	X
Section 10.1.2		X	X
Section 10.2		X	
Section 10.3.1		X	X
Section 10.3.2		X	
Section 10.4.1		X	X
Section 10.5.1		X	X
Section 10.5.2		X	
Section 10.5.3		X	
Chapter 11	X	X	
Chapter 12	X	X	
Chapter 13	X	X	
Chapter 14		X	

Additional information for the development of the DOE Seismic Evaluation Procedure has come from trial applications of the September 1995 Draft at the SRS, Rocky Flats Environmental Technology Center (RFETC), the Los Alamos National Laboratory (LANL), the Stanford Linear Accelerator Center (SLAC) and LLNL. Feedback from these applications of the DOE procedure have been incorporated as appropriate.

The technical review of the DOE Seismic Evaluation Procedure and the endorsement of its use for the DOE is summarized in a letter (Ref. 30) from a technical review committee consisting of Robert Budnitz, Robert Kennedy, and Loring Wyllie. This letter is attached at the end of the Foreward with the following three review comments:

(1) the use of the DOE Seismic Evaluation Procedure is endorsed for the seismic evaluations of existing DOE facilities,

(2) the use of additional equipment categories beyond those in the SQUG GIP is supported for the DOE Seismic Evaluation Procedure, and

(3) the use of the DOE Seismic Evaluation Procedure for new equipment is supported with caution.

It is intended that the DOE Seismic Evaluation Procedure will be revised and updated as appropriate. As screening procedures are developed and reviewed for other classes of equipment, these procedures can be added to the DOE procedure. Section 2.1.3.4 discusses some of the other classes of equipment that can be added to future versions of the DOE procedure. As the SQUG GIP is revised and the information in the earthquake experience database and shake table testing database is enhanced, the appropriate modifications will be made to the DOE Seismic Evaluation Procedure.

1.4.3 Applications at DOE Facilities

The SQUG experience-based seismic evaluation approach has been used at many DOE facilities. The most extensive application has been at the SRS which has reactors that are similar to commercial nuclear power plants. The SRS reactors were built in the 1950s when seismic qualification requirements were in their infancy. SRS became a member of SQUG in 1988, and used the SQUG GIP at its K, L and P reactors to evaluate the seismic adequacy of selected safety systems for their Design Basis Earthquake (DBE). The SRS reactor program included definition of the system scope requiring review; development of SRS facility-specific procedures; use of seismic screening evaluation walkdowns and calculations; and identification, resolution, and upgrading of outliers.

The seismic evaluation program at SRS expands the SQUG GIP in several areas including programmatic changes to enhance engineering assurance. Several technical changes were added to address unique needs at SRS such as additional steps for expansion anchor evaluation, development of capacity for lead cinch anchors, implementation of consistent guidelines for HVAC ducting (Section 10.4.1), and use of experience-based screening guidelines for piping (Section 10.1.1). SRS developed a Seismic Engineering Procedure (SEP-6) (Ref. 3) that includes sections on licensing, the SQUG GIP, and site-specific topics. Portions of the SRS-developed SEP are used in the DOE Seismic Evaluation Procedure.

The SRS seismic evaluation program was judged to be a success with roughly 60% of the items that were evaluated to be seismically adequate as-is. For the others, about 11% were resolved by additional evaluation and the remainder were resolved by upgrade. The typical upgrades consisted of anchorage enhancement and elimination of seismic interaction concerns by providing restraint or removal of the interaction source. The use of the experience-based evaluation approach enabled efficient identification of realistic seismic concerns at SRS. Maximum safety enhancement was achieved with a reasonable engineering effort.

The seismic experience-based approach is currently being used at SRS to evaluate non-reactor facilities. According to Reference 31, seismic qualification using experience data is a technical necessity and is the most economically attractive of the options to qualify existing equipment at SRS. At two SRS facilities, representative costs for seismic qualification using the methodology in the SRS SEP-6 demonstrate costs are 70% lower than the costs for qualification using conventional methods such as seismic testing or detailed engineering analyses.

Similar benefits from use of experience data were realized at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory. Prior to facility restart, seismic verification of essential systems and components had to be demonstrated. Experience-based screening evaluations were used as a key part of the seismic evaluation and upgrade program. Several items were determined to be acceptable in their as-installed configuration. Backfit modifications were installed to increase seismic adequacy as needed. This included providing anchorage for some components, additional restraint for items where deflection considerations governed capacity, and correction of potential seismic systems interaction hazards.

Other applications of using experience data for the evaluation of seismic design issues at DOE facilities include the Princeton Plasma Physics Laboratory, the Idaho Chemical Processing Plant (ICPP), Y-12 at Oak Ridge, and RFETC. At Princeton, active electrical and mechanical equipment, fluid pressure boundary components, and seismic interaction effects were evaluated and resolved by use of experience-based methods. The seismic adequacy of critical fire protection components was evaluated using the experience-based approach at ICPP. Using the methodology in Section 10.1.1, the seismic adequacy of piping systems have been evaluated at Y-12 and RFETC.

The applications at SRS, HFIR, Princeton, and ICPP have proven the viability of using the methodology developed by EPRI / SQUG based on seismic experience data. Many of the results of these evaluations have withstood strict scrutiny during technical audits, peer reviews, quality control audits, and other independent reviews. The approach is also being applied to facilities at LANL, LLNL, and SLAC. Further discussion of the use of experience data for seismic evaluations is provided in Chapter 9 of the "Seismic Safety Manual" (Ref. 32), which was prepared for the DOE. With the experience from the nuclear power industry coupled with numerous applications at DOE sites, the consistent approach in the DOE Seismic Evaluation Procedure for the application of experience data provides DOE sites with an efficient tool for performing their necessary seismic evaluations.

1.4.4 Post-Earthquake Investigations

An important element of the development of the DOE Seismic Evaluation Procedure has been post-earthquake investigations after significant earthquakes. Each significant earthquake provides important lessons that reemphasize and provide new information about designing and retrofitting equipment for strong seismic motion. Since a major component of the EPRI / SQUG methodology is experience data, the data must be appropriately augmented and enhanced with information from recent and significant earthquakes. In many cases, recent earthquakes have provided information which emphasizes the procedures and screens already developed for the EPRI / SQUG methodology.

Post-earthquake investigations are vital to determine if any part of the methodology should be modified or developed further. With each significant earthquake, the experience database will be updated to reflect the results of post-earthquake investigations. Since the DOE Seismic Evaluation Procedure contains classes of equipment and distribution systems that are not included in the SQUG GIP, post-earthquake investigations sponsored by the DOE will focus on these classes of equipment. As data is gathered on these classes of equipment, rigorous procedures for determining equipment capacity can be developed based on the collected information.

Recent earthquakes have provided valuable information about the performance of equipment during seismic strong motion. Details about the performance of industrial facilities and their associated equipment during recent earthquakes are contained in many documents including References 33 and 34. Information in these references emphasizes the response of equipment similar to the types of equipment included in the DOE Seismic Evaluation Procedure. Figures 1.4-1 to 1.4-9 show examples of the performance of equipment, systems, and architectural features subjected to relatively strong seismic motion during recent earthquakes that are similar to the classes of equipment discussed in Chapters 8, 9, 10, and 11.

As appropriate, data from recent earthquakes can be incorporated into the DOE Seismic Evaluation Procedure. In Section 12.2, a potential method for resolving outliers, or equipment that does not meet the intent of the caveats in the DOE Seismic Evaluation Procedure, involves expanding the earthquake experience database to include the equipment or specific features of the equipment. The scope of the earthquake experience data documented in References 19 and 35 represents only a portion of the total data available. Extension of the generic experience equipment classes beyond the descriptions in the DOE Seismic Evaluation Procedure is subject to DOE review and to an external peer review. The external peer review is to be of similar caliber as that required during the original development of the earthquake experience database. An extension of the database must have as rigorous a basis as the information that is currently contained in References 19 and 35.

In addition to post-earthquake investigations, there is a significant amount of seismic data at DOE facilities in the form of shake-table test data. This DOE shake-table test data can be incorporated into the DOE Seismic Evaluation Procedure applying the same considerations for expanding the earthquake experience database as discussed above.

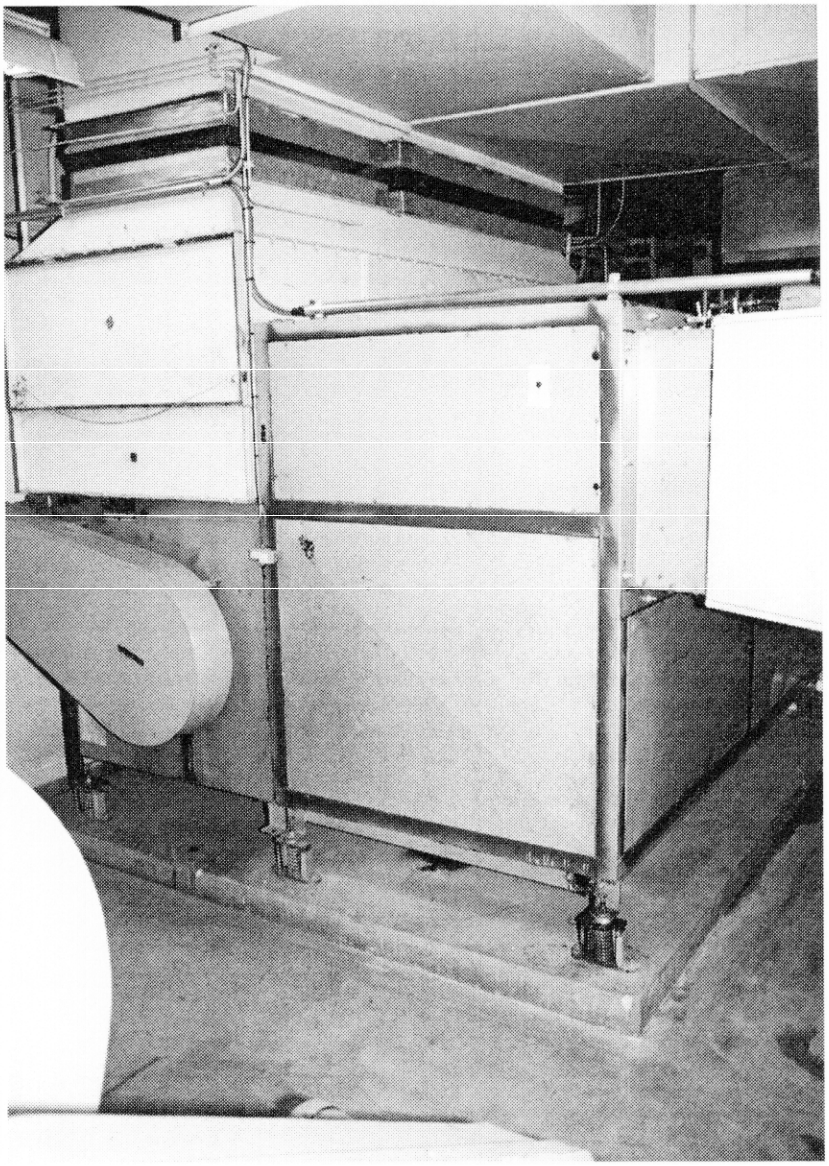

Figure 1.4-1a Shown is an example of vibration isolators without adequate seismic bumpers. This air-handler unit suffered damage at an electrical substation during the 1994 Northridge Earthquake. (Reference 33)

Figure 1.4-1b **Shown is a close-up of vibration isolators without adequate seismic bumpers. (Reference 33)**

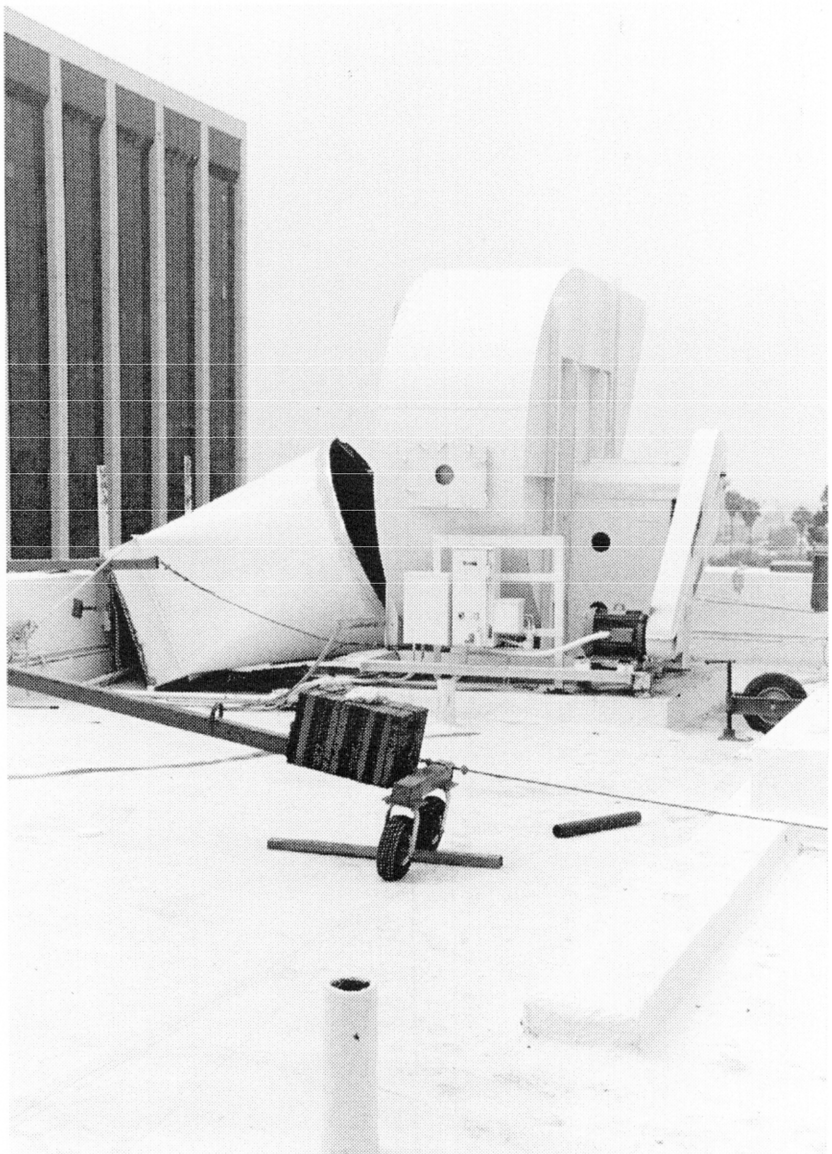

Figure 1.4-2 On the roof of a six-story hospital, a plenum pulled loose from its fan enclosure during the 1994 Northridge Earthquake. (Reference 33)

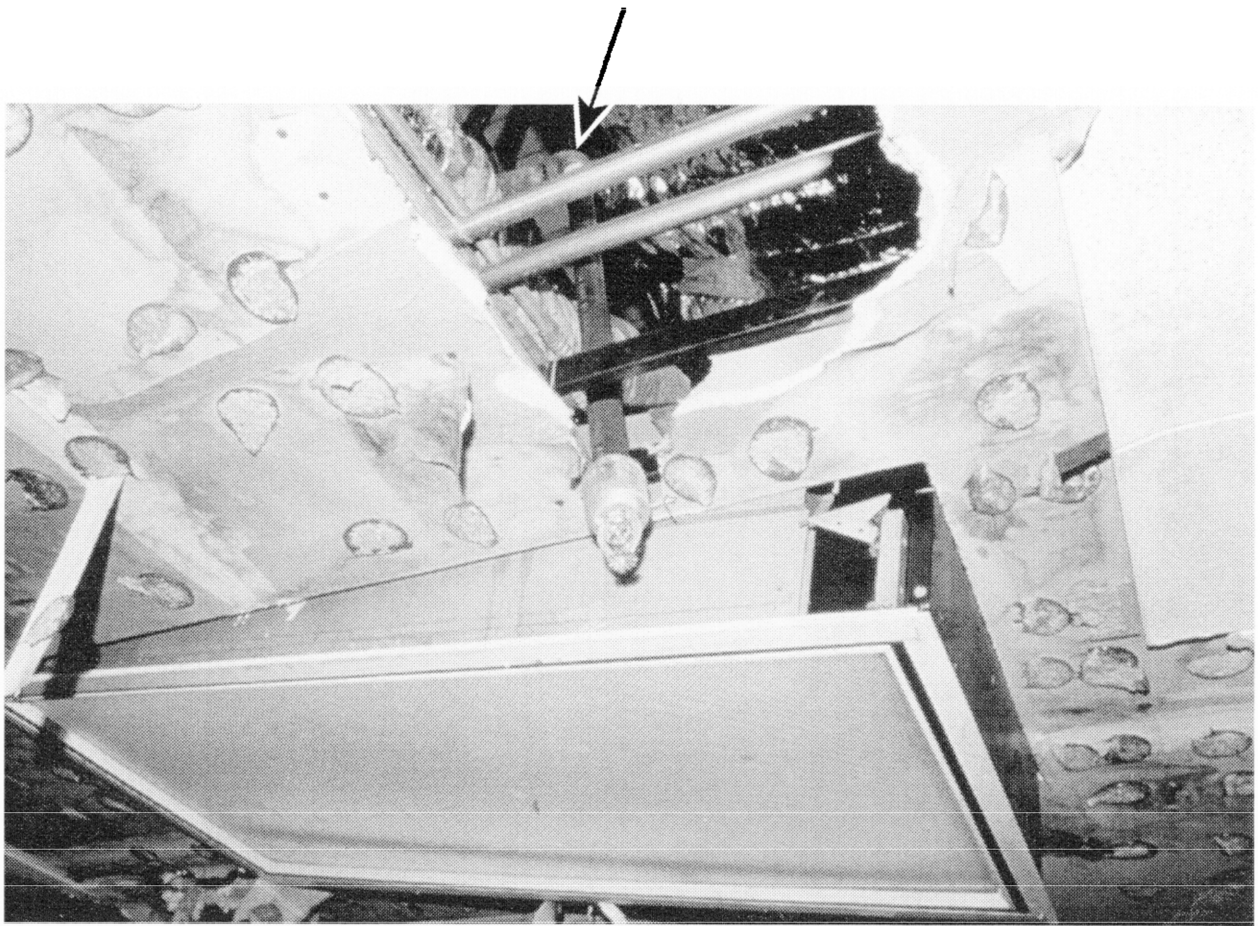

Figure 1.4-3 Water spray following an earthquake was a major seismic interaction issue during and directly after the 1994 Northridge Earthquake. As shown in this figure, fire sprinkler piping broke at threaded elbow joints of the vertical branches that suspend the sprinkler heads. Damage to the fire sprinkler piping at several facilities caused these facilities to shut down following the earthquake, even though the buildings had no structural damage. (Reference 33)

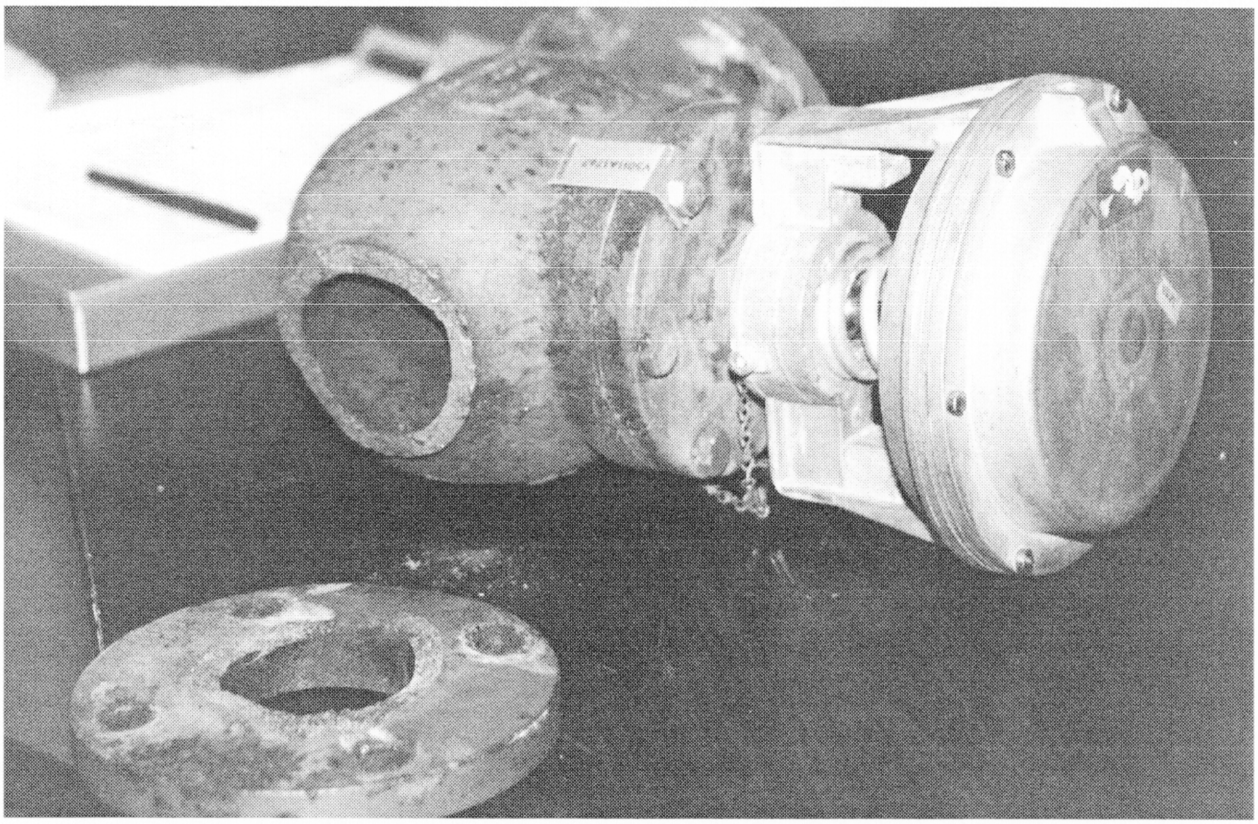

Figure 1.4-4 In a penthouse above the sixth story of a hospital, a cast-iron valve body failed near its flange due to inertial forces on a 4-inch diameter chilled water line and allowed water to leak down to the floors below. This occurred during the 1994 Northridge Earthquake. (Reference 33)

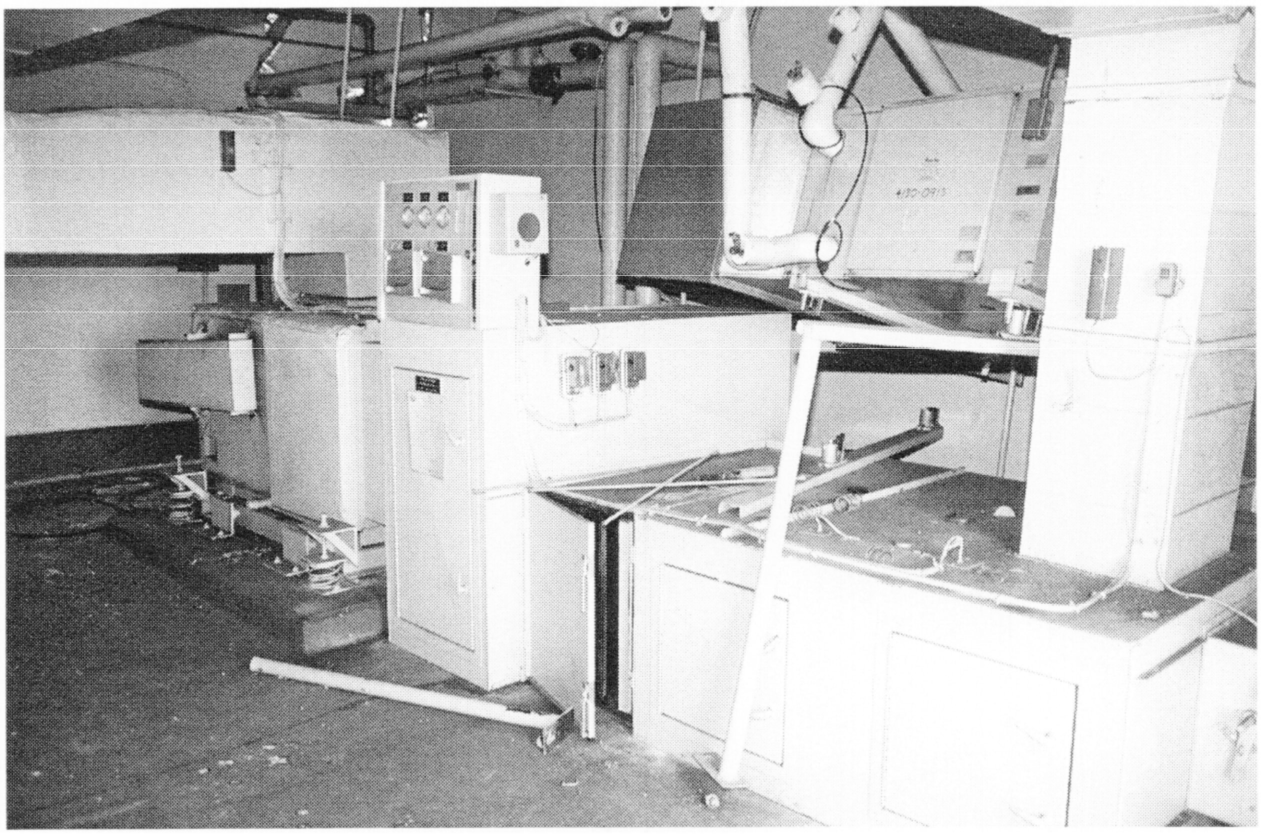

Figure 1.4-5 **As a result of the pounding between the wings of a six-story building during the 1994 Northridge Earthquake, a fan came off of its support frame inside a penthouse. (Reference 33)**

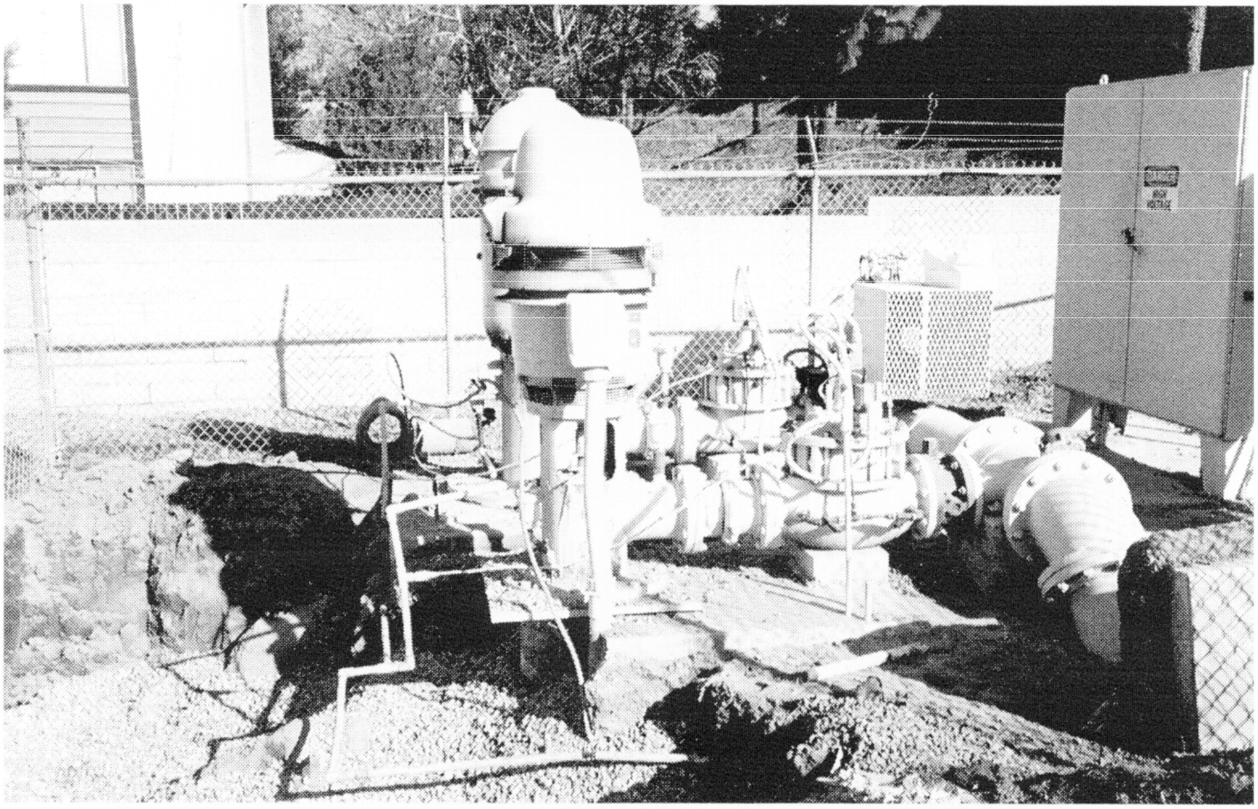

Figure 1.4-6a **Ground settlement at this lift station caused underground attached piping to crack and leak after the 1994 Northridge Earthquake. (Reference 33)**

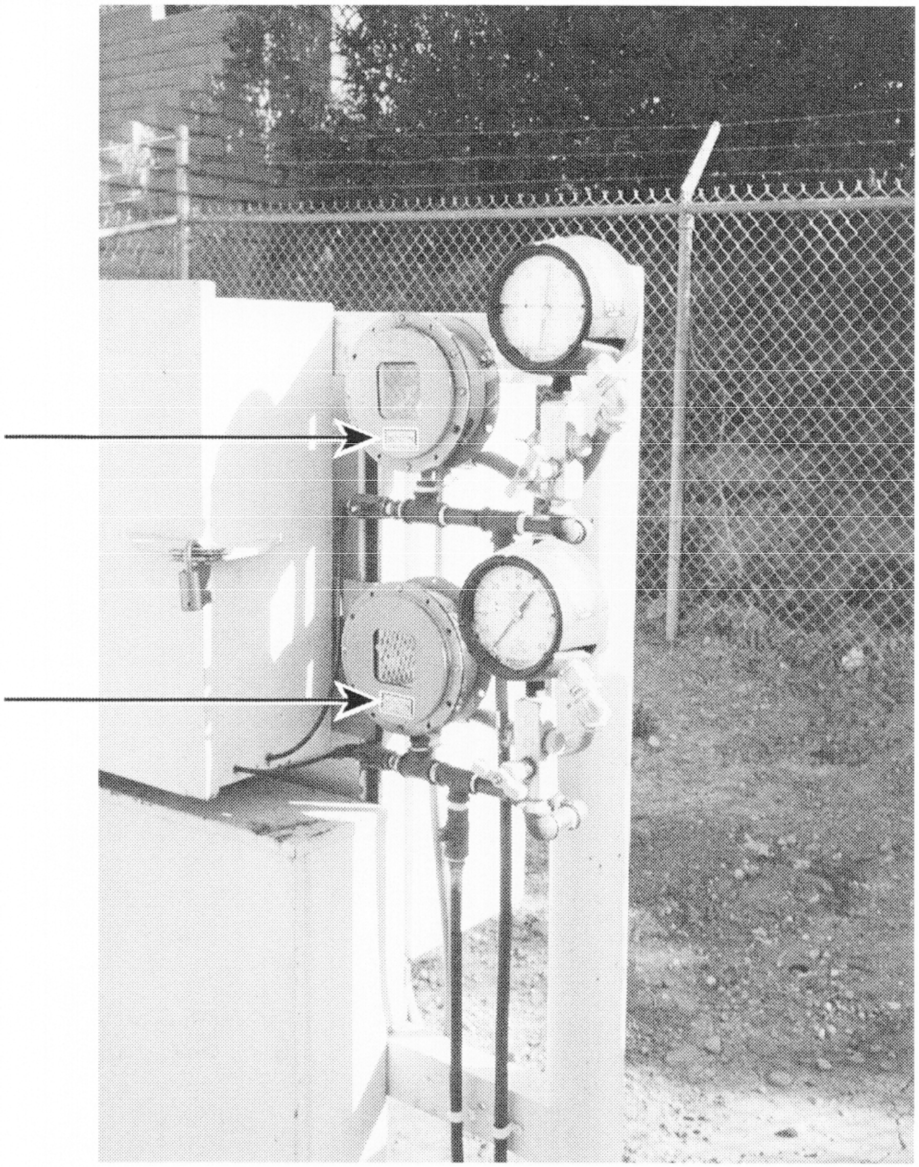

Figure 1.4-6b Mercoid Switches connected to the pressure transmitters at a lift station may have caused an inadvertent trip of relays, or change of state of the control system. (Reference 33)

Figure 1.4-7a This vertical, flat-bottom tank experienced the 1995 Kobe Earthquake (note both the flexible connection for the attached piping and the stretched/pulled anchor bolts at the base of the tank). (Reference 34)

Figure 1.4-7b **Close-up of one of the anchor bolts which appeared to have experienced a combination of partial pull-out as well as stretching of the bolt as the tank tried to rock. (Reference 34)**

Figure 1.4-8a **Shown is a ductwork trapeze that is partially collapsed. During the 1995 Kobe Earthquake, one of the expansion anchors for the threaded rod support pulled out of the reinforced concrete ceiling. (Reference 34)**

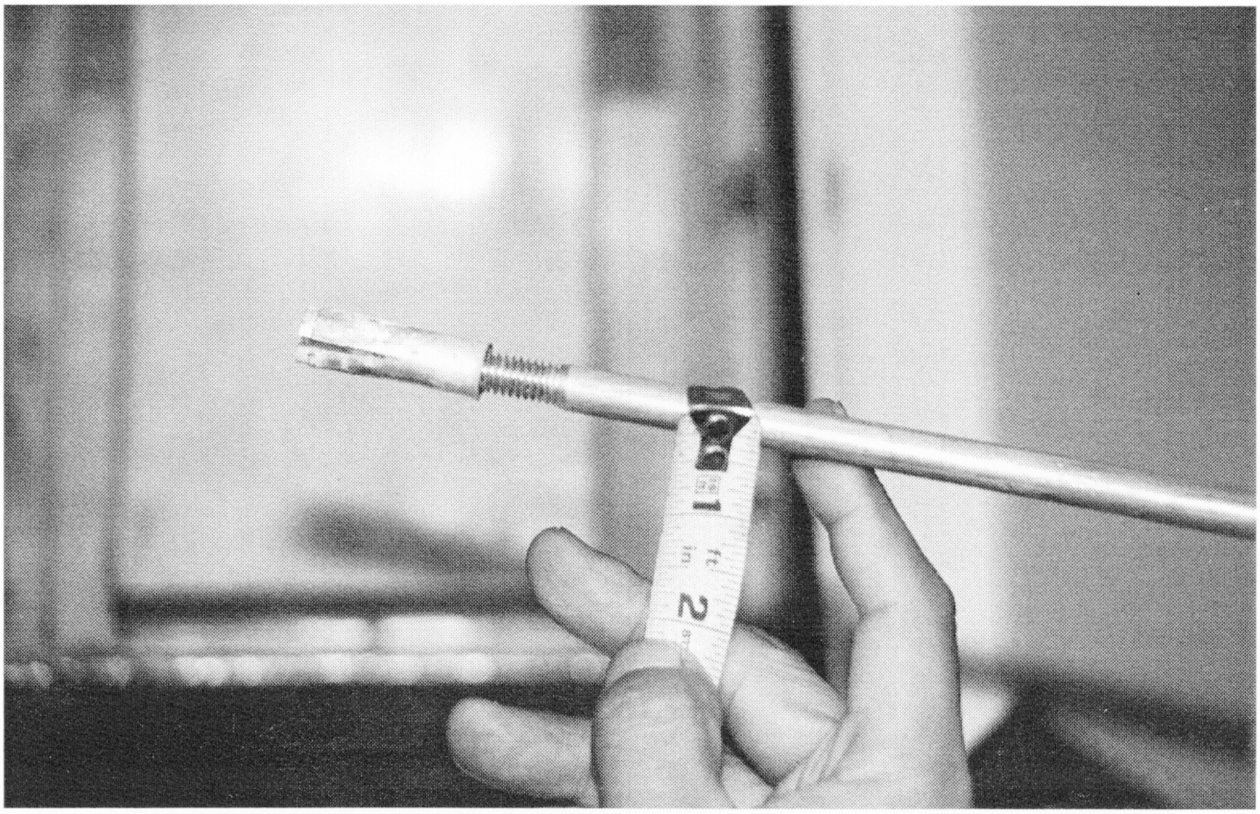

Figure 1.4-8b **Shown is a close-up of the expansion anchor which pulled out of the reinforced concrete ceiling. It appears that there was inadequate expansion of the shell. (Reference 34)**

Figure 1.4-9 Large diagonal cracks in unreinforced masonry cladding (one-width thickness) over a reinforced concrete frame in an L-shaped building experienced damage during the 1994 Northridge Earthquake. (Reference 36)

1.5 DOE LICENSE FOR EPRI / SQUG MATERIAL

An important step toward development of the comprehensive natural phenomena hazard evaluation guidelines for systems and components at DOE facilities was obtaining the proprietary reference documents and procedures developed by SQUG and EPRI. This was a key element of the DOE evaluation program because it allows DOE to take advantage of all the work performed to-date for several classes of equipment at commercial nuclear reactors. The EPRI / SQUG material is arranged into six volumes and copies of the material have been distributed throughout the DOE. Within the volumes there are twelve key reference reports (Ref. 35 and 40 to 50) that cover the technical areas of 20 classes of equipment, anchorage, electrical raceways, relays, and tanks and heat exchangers. A document which develops a methodology for assessment of nuclear power plant seismic margin (Ref. 18) is also available to the DOE. In addition, the SQUG GIP is contained in the volumes of material as a basis document for the DOE Seismic Evaluation Procedure. There are several documents in the volumes that summarize the SSRAP and NRC review of the EPRI / SQUG methodology (Ref. 2, 19, and 50) and provide additional information for piping and ducting systems (Ref. 39 and 51 to 55).

The EPRI / SQUG Seismic Assessment Material is available for use when performing seismic evaluations of DOE facilities under a written licensing agreement between EPRI and LLNL. Control and use of the EPRI / SQUG Material is by a procedure (Ref. 56) that applies to all DOE staff; Management and Operations (M&O) contractor staff; and subcontractors, who are currently under contract to DOE or a M&O, to conduct seismic evaluations of DOE facilities. DOE, M&O, and contractor staff may only obtain the EPRI / SQUG Material by attending a training course sponsored by DOE. All personnel who are issued a controlled set of the Material sign an acknowledgment receipt form to comply with the requirements of the procedure.

According to the procedure, all personnel having a controlled copy of the Material may use and reference the Material while performing seismic assessments of DOE facilities. In addition, the Material may be loaned within a particular DOE site by its custodian. Volumes 1 and 8 of the Material have no restrictions on its use. The SQUG GIP in Volume 2 is copyrighted by SQUG and should not be reproduced. Volumes 3 through 7 of the Material shall not be reproduced and its ownership shall not be transferred to any other personnel without following the established procedure. As discussed in Section 3.4, the Material is only issued to personnel and may only be used by personnel who attend a DOE-sponsored training course (see Section 3.4) that instructs attendees on its proper use. Attendance at the training courses and the receipt of the Material are documented by DOE.

2. SCREENING EVALUATION AND WALKDOWN PROCEDURE

2.1 APPROACH IN THE DOE SEISMIC EVALUATION PROCEDURE[1]

The approach used in the DOE Seismic Evaluation Procedure for evaluating the seismic adequacy of equipment in DOE facilities is consistent with the intent of DOE Policy, Orders, and Standards. It is also consistent with the approach in the SQUG GIP (Ref. 1) and the EPRI Seismic Margins Assessment Program (Ref. 18). The four major steps used in the DOE procedure for the majority of the equipment to be evaluated are listed below, along with the chapter(s) of the procedure where these steps are covered in detail:

- Selection of Seismic Evaluation Personnel (Chapter 3)
- Determination of Seismic Equipment List (Chapter 4)
- Screening Evaluation and Walkdown

  Capacity versus Demand (Chapter 5)

  Anchorage (Chapter 6)

  Seismic Interaction (Chapter 7)

  Equipment Class Evaluations (Chapters 8, 9, and 10)

  Relay Functionality (Chapter 11)
- Outlier Identification and Resolution (Chapter 12)

The suggested documentation for these reviews is discussed in each of the chapters and in Chapter 13. The remainder of this section summarizes the material covered in Chapters 3 through 13.

An important aspect of the methodology in the DOE Seismic Evaluation Procedure is the use of judgment that results from appropriate training, extensive experience with walkdowns, and review of the reference documents for the SQUG GIP. Guidance and discussion about the use of engineering judgment are provided in References 18, 57, and 58 that discuss the assessment of seismic margins for nuclear power plants. Since the level of expertise will differ with the seismic evaluation personnel as discussed in the following section, it is vital that the personnel identify the equipment that they do and do not have the adequate level of expertise to evaluate and that they evaluate only the equipment for which they have the appropriate experience. Engineers who use the DOE Seismic Evaluation Procedure are responsible for its appropriate application, for their level of training, and for their use of judgment. <u>The developers of the Procedure assume no responsibility for specific applications of the methodology</u>.

2.1.1 <u>Seismic Evaluation Personnel</u>[2]

Individuals from several engineering disciplines, their recommended minimum requirements or qualifications, and their responsibilities for implementing this Seismic Evaluation Procedure are described in Chapter 3. These individuals include: (1) Safety Professionals and Systems Engineers who identify the methods and the equipment needed in the Seismic Equipment List

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1 Based on Section 1.3 of SQUG GIP (Ref. 1)

2 Based on Section 1.3.1 of SQUG GIP (Ref. 1)

(SEL); (2) Operations Personnel who have a comprehensive understanding of the facility layout, the function and operation of the equipment and systems in the facility, and the facility operating procedures; (3) Seismic Capability Engineers (SCEs) who perform the Screening Evaluation and Walkdown of the equipment listed in the SEL; (4) Relay Evaluation Personnel who perform the relay functionality review; and (5) Piping Evaluation Engineers who perform the walkdown and evaluation of piping listed in the SEL.

Since the instructions and requirements contained in this procedure are guidelines and not fixed, inflexible rules, the SCEs must exercise sound engineering judgment during the Screening Evaluation and Walkdown. Therefore, the selection and training of qualified SCEs for participation on the Seismic Review Teams (SRTs) is an important element of the DOE Seismic Evaluation Procedure. The SCEs are expected to exercise engineering judgment based upon an understanding of the guidelines given in the procedure, the basis for these guidelines given in the reference documents and presented in the DOE training course, and their own seismic engineering experience.

Chapter 3 also describes the DOE-developed training course which should be taken by individuals who perform the seismic review of a DOE facility with the DOE Seismic Evaluation Procedure. This course provides assurance that there is a minimum level of understanding and consistency in applying the guidelines contained in this procedure.

2.1.2 Seismic Equipment List

The Seismic Equipment List (SEL) is described in Chapter 4. This list is typically developed by Safety Professionals and Systems Engineers in consultation with Operations Personnel and other engineers. Equipment listed on the SEL is evaluated by SCEs using the screening and walkdown methodology of the Seismic Evaluation Procedure.

Screening guidelines are provided in the DOE Seismic Evaluation Procedure for evaluating the seismic adequacy of most types of equipment which could be listed in the SEL. However, if an item of equipment listed in the SEL is not covered by the screening guidelines, then it is identified as an outlier and evaluated separately as discussed in Chapter 12.

2.1.3 Screening Evaluation and Walkdown[3]

The Screening Evaluation and Walkdown of equipment listed in the SEL is described in Chapters 5 through 11. The purpose of the Screening Evaluation and Walkdown is to screen out from further consideration those items of equipment that pass certain generic, seismic adequacy criteria. The screening evaluation is based heavily on the use of seismic experience data. If the equipment does not pass the screens, other more refined or sophisticated methods for evaluating the seismic adequacy of the equipment may be used as described in Chapter 12.

The procedure for performing the Screening Evaluation and Walkdown is depicted in Figure 2.1-1. As shown in the figure, each of the following four seismic screening guidelines should be used to evaluate the seismic adequacy of an item of equipment:

- Seismic Capacity Compared to Seismic Demand (Chapter 5) - The seismic capacity of the equipment, based on earthquake experience data, generic seismic testing data, or equipment-specific seismic qualification data, should be greater than the seismic demand imposed on the equipment, system, or architectural feature.

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[3] Based on Section 4.0 of SQUG GIP (Ref. 1)

- Anchorage (Chapter 6) - The equipment anchorage capacity, installation, and stiffness should be adequate to withstand the seismic demand at the equipment location.

- Seismic Interaction (Chapter 7) - The effect of possible seismic spatial interactions with nearby equipment, systems, and structures and interaction from water spray, flooding, and fire hazards should not cause the equipment to fail to perform its intended function.

- Equipment Class Evaluations (Chapters 8, 9, and 10) - In Chapter 8, the equipment must be similar to the equipment in the earthquake experience equipment class or the generic seismic testing equipment class and also meet the intent of the specific caveats for that class of equipment in order to use the seismic capacity defined by the earthquake experience Reference Spectrum or the generic seismic testing GERS. If equipment-specific seismic qualification data is used, then specific restrictions or caveats for that qualification data apply instead. In Chapter 9, the equipment must be similar to the equipment in the earthquake experience equipment class, meet the caveats, and satisfy the screening procedures. In Chapter 10, the equipment must be similar to the equipment classes and be evaluated using the general screening procedures or guidelines.

The evaluation of equipment against each of these four screening guidelines is to be based upon walkdown evaluations, calculations, and other supporting data. While equipment seismic evaluations can generally be performed independently from each other, there are a few areas where an interface with the Relay Functionality Review (Chapter 11) is appropriate:

- Any cabinets containing essential relays, as determined by the relay review in Chapter 11, should be evaluated for seismic adequacy using the guidelines contained in Chapter 8.

- Apply a capacity reduction factor to expansion anchor bolts that secure cabinets containing essential relays. This capacity reduction factor is discussed in Chapter 6.

- Seismic interaction, including even mild bumping, is not allowed on cabinets containing essential relays. This limitation is discussed in Chapters 7, 8, and 11.

- In-cabinet amplification factors for cabinets containing essential relays are to be estimated by the SCEs for use in the Relay Functionality Review.

It is suggested that items of equipment containing essential relays be identified prior to the Screening Evaluation and Walkdown so that the above evaluations may be accomplished during the Screening Evaluation and Walkdown.

2.1.3.1 Seismic Capacity Compared to Seismic Demand[4]

A screening guideline to be satisfied to evaluate the seismic adequacy of an item of equipment is to confirm that the seismic capacity of the equipment is greater than or equal to the seismic demand imposed on it. Chapter 5 addresses the comparison of seismic capacity to seismic demand for the equipment classes discussed in Chapter 8. The seismic capacity of an item of equipment can be compared to a seismic demand spectrum (SDS) defined in terms of an in-structure response spectrum (IRS) with the applicable scale factors. In Chapter 9 and parts of Chapter 10, specific methods for comparing seismic capacity to seismic demand are developed for several classes of equipment. In addition, a comparison of seismic capacity to seismic demand is made in Chapter 6 for the anchorage of the equipment and in Chapter 11 for relays mounted in the equipment.

[4] Based on Sections 4.2, 4.2.1, and 4.2.2 of SQUG GIP (Ref. 1)

The seismic capacity of equipment can be represented by a "Reference Spectrum" based on earthquake experience data, or a "Generic Equipment Ruggedness Spectrum" (GERS) based on generic seismic test data. Note that these two methods of representing seismic capacity of equipment can only be used if the equipment meets the intent of the caveats for its equipment class as described in Chapter 8.

Earthquake experience data was obtained by surveying and cataloging the effects of strong ground motion earthquakes on various classes of equipment mounted in conventional facilities and other industrial facilities. The results of this effort are summarized in Reference 35. Based on this work, a "Reference Spectrum" was developed representing the seismic capacity of equipment in the earthquake experience equipment class. A detailed description of the derivation and use of this Reference Spectrum is contained in Reference 19 and this reference should be reviewed by the SCEs before using the Reference Spectrum. The Reference Spectrum, which is shown in Chapter 5, can be used to represent the seismic capacity of equipment in a DOE facility when this equipment is determined to have characteristics similar to the earthquake experience equipment class and meets the intent of the caveats for that class of equipment as defined in Chapter 8. Use of the Reference Spectrum for comparison with a SDS is described in Chapter 5.

A large amount of data was also collected from seismic qualification testing of equipment. This data was used to establish a generic ruggedness level for various equipment classes in the form of Generic Equipment Ruggedness Spectra (GERS). The development of the GERS and the limitations on their use (caveats) are documented in Reference 40. Copies of the non-relay GERS along with a summary of the caveats to be used with them are included in Chapter 8. SCEs should review Reference 40 to understand the basis for the GERS. GERS can be used to represent the seismic capacity of an item of equipment in a DOE facility when this equipment is determined to have characteristics that are similar to the generic testing equipment class and meets the intent of the caveats for that class of equipment as defined in Chapter 8. Use of the GERS for comparison to a SDS is described in Chapter 5.

2.1.3.2 Anchorage Adequacy[5]

A screening guideline to be satisfied to evaluate the seismic adequacy of an item of equipment is to confirm that the anchorage of the equipment is adequate. Lack of anchorage or inadequate anchorage has been a significant cause of equipment failing to function properly during and following past earthquakes.

The screening approach for evaluating the seismic adequacy of equipment anchorage is based upon a combination of inspections, analyses, and engineering judgment. Inspections consist of measurements and visual evaluations of the equipment and its anchorage, supplemented by use of facility documentation and drawings. Analyses should be performed to compare the anchorage capacity to the seismic loads (demand) imposed upon the anchorage. These analyses should be done using the guidelines contained in Chapter 6. Engineering judgment is an important element in the evaluation of equipment anchorage. Guidance for making judgments is included, where appropriate, in Chapter 6 and in the reference documents.

Section 6.4.1 contains methods for determining or estimating the natural frequency and damping of many of the classes of equipment in Chapters 8, 9, and 10. Generic equipment characteristics are provided for motor control centers, low-voltage switchgear, medium-voltage switchgear, transformers, horizontal pumps, vertical pumps, air compressors, motor-generators, batteries on racks, battery chargers and inverters, engine-generators, instrument racks, equipment cabinets, and control panels.

[5] Based on Section 4.4 of SQUG GIP (Ref. 1)

There are various combinations of inspections, analyses, and engineering judgment that can be used to evaluate the adequacy of equipment anchorage. The SCEs should select the appropriate combination of elements for each anchorage installation based on the information available. For example, a simple hand calculation may be sufficient for a pump that has only a few, very rugged, anchor bolts in a symmetrical pattern. On the other hand, at times it may be advisable to use one of the anchorage computer codes to determine the loads applied to a multi-cabinet motor control center if its anchorage is not symmetrically located. Likewise a trade-off can be made between the level of inspection performed and the factor of safety used for expansion anchor bolts. These types of trade-offs and others are discussed in Chapter 6.

2.1.3.3 Seismic Interaction[6]

A screening guideline to be satisfied to evaluate the seismic adequacy of an item of equipment is to confirm that there are no adverse seismic spatial interactions with nearby equipment, systems, and structures and interaction from water spray, flooding, and fire hazards that could cause the equipment to fail to perform its intended function. The interactions of concern are potential impact due to proximity, structural failure and falling, and flexibility of attached lines and cables. Guidelines for judging interaction effects when evaluating the seismic adequacy of equipment are presented in Chapter 7.

It is the intent of the seismic interaction evaluation that real (i.e., credible and significant) interaction hazards be identified and evaluated. The interaction evaluations described in Chapter 7 focus on areas of concern based on past earthquake experience. Systems and equipment that have not been specifically designed for seismic loads should not be arbitrarily assumed to fail under earthquake loads; instead, SCEs are expected to differentiate between likely and unlikely interactions, using their judgment and past earthquake experience. In addition, system interaction effects as defined in DOE-STD-1021 (Ref. 7) are also discussed in Chapter 7.

Note that special attention should be given to the seismic interaction of electrical cabinets containing relays. If the relays in the electrical cabinets are essential (i.e., the relays should not chatter during an earthquake), then any impact on the cabinet should be considered an unacceptable seismic interaction and cause for identifying that item of equipment as an outlier. Guidance for evaluating the consequences of relay chatter due to earthquake motions, including cabinet impact interactions, are presented in Chapter 11 and Reference 45.

2.1.3.4 Equipment Class Evaluations[7]

A screening guideline to be satisfied to evaluate the seismic adequacy of an item of equipment is to confirm that (1) the equipment characteristics are generally similar to the earthquake experience equipment class or the generic seismic testing equipment class and (2) the equipment meets the intent of the specific caveats, procedures, or guidelines for the equipment class.

The DOE Seismic Evaluation Procedure has three different types of equipment class evaluations with varying levels of rigor and technical review. Table 2.1-1 lists all the equipment classes contained in the DOE Seismic Evaluation Procedure and the type of evaluation for each equipment class.

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[6] Based on Section 4.5 of SQUG GIP (Ref. 1)
[7] Based on Section 4.3 of SQUG GIP (Ref. 1)

- Chapter 8 contains caveats that permit the rigorous use of the Reference Spectrum and/or GERS to define the seismic capacity of the equipment classes. The twenty classes of equipment and the procedures in Chapter 8 are from Revision 2 of the SQUG GIP. The procedures in Chapter 8 were independently reviewed by the Senior Seismic Review and Advisory Panel (SSRAP) as part of the SQUG program and were approved by the NRC with a safety evaluation report (Ref. 2).

- Chapter 9 contains equipment class evaluations based on rigorous screening procedures from Revision 2 of the SQUG GIP. The procedures in Chapter 9 were independently reviewed by SSRAP as part of the SQUG program and were approved by the NRC with a safety evaluation report (Ref. 2).

- Chapter 10 contains screening procedures and general guidelines for equipment classes that are not provided in the SQUG GIP and are found at DOE facilities. Sections 10.1.1, 10.4.1, and 10.5.1 contain relatively rigorous screening procedures. Sections 10.2, 10.3.2, 10.5.2, and 10.5.3, on the other hand, contain guidelines that are not rigorous, but are intended to provide cost-effective and achievable techniques for increasing the seismic capacity of equipment classes in those sections. Finally, Sections 10.3.1 and 10.1.2 are summarized versions of several chapters of a DOE document. The technical review of the Sections in Chapter 10 is discussed in Section 1.4.2.

In addition to the classes of equipment in the SQUG GIP, twenty additional classes of equipment were identified as potentially requiring seismic evaluation at DOE sites. These additional classes of equipment were identified based on the responses from questionnaires sent to DOE sites and Chapter 10 contains about half of the identified classes of equipment. As the screening procedures and guidelines for additional classes of equipment are developed and reviewed, they can be added to Chapter 10 of the DOE Seismic Evaluation Procedure. In addition, the rigor of some of the sections in Chapter 10 can be enhanced with further development and review. Other classes of equipment that exist at DOE facilities that could be added to the DOE Seismic Evaluation Procedure include:

electrical equipment - distributed control systems, computer equipment, alarm and security equipment, communication equipment, and miscellaneous electrical equipment

mechanical equipment - ventilation dampers

tanks - elevated tanks, boilers, and miscellaneous tanks

piping and raceway systems - stacks, tubing, bus ducts, and conveyors of material

architectural features - suspended ceilings, cranes, and elevators

switchyard and substation equipment - power transformers, circuit breakers, disconnect switches, current and voltage transformers, surge and lightning arresters, wave traps, capacitor banks, buswork, and miscellaneous switchyard equipment

Table 2.1-1 Equipment Class Evaluations in the DOE Seismic Evaluation Procedure

Section	Equipment Class	Type of Evaluation
	ELECTRICAL EQUIPMENT	
8.1.1	Batteries on Racks	Caveats
8.1.2	Motor Control Centers	Caveats
8.1.3	Low-Voltage Switchgear	Caveats
8.1.4	Medium-Voltage Switchgear	Caveats
8.1.5	Distribution Panels	Caveats
8.1.6	Transformers	Caveats
8.1.7	Battery Chargers and Inverters	Caveats
8.1.8	Instrumentation and Control Panels	Caveats
8.1.9	Instruments on Racks	Caveats
8.1.10	Temperature Sensors	Caveats
	MECHANICAL EQUIPMENT	
8.2.1	Fluid-Operated / Air-Operated Valves	Caveats
8.2.2	Motor-Operated / Solenoid-Operated Valves	Caveats
8.2.3	Horizontal Pumps	Caveats
8.2.4	Vertical Pumps	Caveats
8.2.5	Chillers	Caveats
8.2.6	Air Compressors	Caveats
8.2.7	Motor-Generators	Caveats
8.2.8	Engine-Generators	Caveats
8.2.9	Air Handlers	Caveats
8.2.10	Fans	Caveats
10.2.1	HEPA Filters	General Guidelines
10.2.2	Glove Boxes	General Guidelines
10.2.3	Miscellaneous Machinery	General Guidelines
	TANKS	
9.1.1	Vertical Tanks	Screening Procedure
9.1.2	Horizontal Tanks and Heat Exchangers	Screening Procedure
10.3.1	Underground Tanks	General Guidelines
10.3.2	Canisters and Gas Cylinders	General Guidelines
	PIPING, RACEWAY, AND DUCT SYSTEMS	
9.2.1	Cable and Conduit Raceway Systems	Screening Procedure
10.1.1	Piping	Screening Procedure
10.1.2	Underground Piping	General Guidelines
10.4.1	HVAC Ducts	Screening Procedure
	ARCHITECTURAL FEATURES AND COMPONENTS	
10.5.1	Unreinforced Masonry (URM) Walls	Screening Procedure
10.5.2	Raised Floors	General Guidelines
10.5.3	Storage Racks	General Guidelines

2.1.3.4.1 Rule of the Box[8]

An important aspect of evaluating the seismic adequacy of equipment included within the scope of this procedure is explained by the "rule of the box". "Rule of the box" applies to "normal" components of equipment, or parts of the equipment that are included in the earthquake experience database or shake table tests database. The intent of the "rule of the box" for equipment included in either the earthquake or testing equipment database is that all of the components mounted on or in this equipment are considered to be part of that equipment and do not have to be evaluated separately. Auxiliary components that are not mounted on the item of equipment but are needed by the equipment to fulfill its intended function need to be evaluated separately. Peer review, as discussed in Section 2.2, is needed to evaluate if the earthquake experience database or shake table tests database provides the basis for a particular application of the "rule of the box".

A typical example of the "rule of the box" is a diesel generator which not only includes the engine block and generator, but also all other items of equipment mounted on the diesel generator or on its skid; such as the lubrication system, fuel supply system, cooling system, heaters, starting systems, and local instrumentation and control systems. Components needed by the diesel generator but not included in the "box" (i.e., not mounted on the diesel generator or on its skid) are to be identified and evaluated separately. Typically this would include such items as off-mounted control panels, air-start compressors and tanks, batteries, pumps for circulating coolant and lubricant, day tanks, and switchgear cabinets.

An obvious advantage to the "rule of the box" is that only the major items of equipment need be evaluated for seismic adequacy (and only documented once), i.e., if a major item of equipment is shown to be seismically adequate using the guidelines in this procedure, then all of the parts and components mounted on or in that item of equipment are also considered seismically adequate. Typically, the "rule of the box" applies for components attached to the equipment before the first anchor point of the equipment. However, the SCEs should exercise their judgment and experience to seek out suspicious details or uncommon situations (those which are "out of the ordinary", are not specifically covered in the equipment class evaluations, or are site add-ons) that may make that item of equipment vulnerable to earthquake effects. This evaluation should include any areas of concern within the "box" which could be seismically vulnerable, such as added attachments, missing anchorage, or obviously inadequate anchorage of components.

One exception to the "rule of the box" is relays (and other types of device using contacts in the control circuitry). Even though relays are mounted on or in another larger item, they should be identified and evaluated for seismic adequacy using the procedure described in Chapter 11 since they may be susceptible to chatter during seismic excitation. The relays to be evaluated are identified by first identifying the major item of equipment for the SEL which could be affected if the relays malfunctioned. Then, in Chapter 11, the particular relays used to control these major items of equipment are determined and evaluated for seismic adequacy.

2.1.3.4.2 Equipment Class Evaluations Using Caveats for the Reference Spectrum and/or GERS (Chapter 8)[9]

Chapter 8 contains a summary of equipment class descriptions based on earthquake experience data and generic seismic testing data. These descriptions and the rest of Chapter 8 is from Appendix B of Revision 2 of the SQUG GIP. An item of equipment must have the same general characteristics as the equipment in the earthquake experience equipment class or the generic seismic testing equipment class to apply the methodology in Chapter 8. The intent of this rule is to preclude items

[8] Based on Section 3.3.3 of SQUG GIP (Ref. 1)
[9] Based on Section 4.3 of SQUG GIP (Ref. 1)

of equipment with unusual designs and characteristics that have not demonstrated seismic adequacy in earthquakes or tests.

"Caveats" are defined as the set of inclusion and exclusion rules that represent specific characteristics and features particularly important for seismic adequacy of a particular class of equipment. Chapter 8 contains a summary of the caveats for the earthquake experience equipment class and for the generic seismic testing equipment class. If the caveats are satisfied, then the capacity of the equipment class can be represented by the Reference Spectrum and/or the GERS. For these equipment classes, extensive use of earthquake experience and test data permits the rigorous definition of the equipment capacity and evaluation of the seismic adequacy of the equipment. The equipment capacity determined in Chapter 8 is compared to the seismic demand using the provisions of Chapter 5.

The "intent" of the caveats should be met when evaluating an item of equipment as they are not fixed, inflexible rules. Engineering judgment may be used to determine whether the specific seismic concern addressed by the caveat is met. Chapter 8 provides brief discussions of the intent of the caveats. When specific cases are identified where the intent of the caveats are considered to be met, but the specific wording of the caveat rule is not, the reason for this conclusion should be documented.

Note that the caveats in Chapter 8 are not necessarily a complete list of every seismically vulnerable detail that may exist since it is impossible to cover all such situations by meaningful caveats. Instead, the SCEs should exercise their judgment and experience to seek out suspicious details or uncommon situations (not specifically covered by the caveats) which may make equipment vulnerable to earthquake effects. For example, the SCEs should note any areas of concern within the "box" which could be seismically vulnerable such as added attachments, missing or obviously inadequate anchorage of components, heavy objects mounted on the equipment, and components that are known to be seismically sensitive.

The summaries of the equipment class descriptions and caveats in Chapter 8 are based on information contained in References 19, 35, and 40. Additional information on seismic experience data is contained in Chapter 9d of Reference 32. The SCEs should use the summaries in Chapter 8 only after first thoroughly reviewing and understanding the background of the equipment classes and bases for the caveats as described in these references. These references provide more details (such as photographs of the data base equipment) and more discussion than summarized in Chapter 8. Note that in some cases, clarifying remarks have been included in Chapter 8 that are not contained in the reference documents. These clarifying remarks include such things as the reason for including a particular caveat, the intent of the caveat, and recommended allowable limits for stress analysis. The remarks are also based on experience gained during SQUG GIP reviews at operating nuclear power plants and DOE seismic evaluations at DOE facilities and they serve to help guide the SCEs in their judgment.

Certain important caveats from the reference documents are not included in Chapter 8 because they are covered in other sections of the DOE Seismic Evaluation Procedure. These caveats include:

- Equipment should be adequately anchored and base isolation should be carefully evaluated (see Chapter 6).
- Seismic interaction concerns, such as flexibility of attached lines, should not adversely affect the equipment (see Chapter 7).
- Relays for which chatter is not acceptable should be specifically evaluated. Note that although the primary responsibility for conducting the relay evaluation is the Lead Relay Reviewer, the SCEs should be alert for any seismically induced systems effects that may lead to loss of function or malfunction of the equipment being evaluated (see Chapter 11).

In addition, caveats discussing a limiting fundamental frequency of 8 Hz are not included in Chapter 8 because this limiting frequency does not apply with the provisions of Chapter 5.

Chapter 8 is organized by equipment class as listed in Table 2.1-2. For each equipment class, the class description and the caveats applicable to the Reference Spectrum are given first. A plot of the Reference Spectrum is provided in Chapter 5. Next, the class description and the caveats applicable to the GERS are given, when available. Some equipment classes have more than one GERS while other classes have none. A plot of the GERS follows the caveats for each applicable equipment class. While the GERS typically define a higher capacity, the GERS caveats are more restrictive than the reference spectrum caveats.

Table 2.1-2 Equipment Class Evaluations Using Caveats for the Reference Spectrum and/or GERS (SQUG GIP, Reference 1)

Section	Equipment Class	Reference Spectrum	GERS
8.1.1	Batteries on Racks	X	X
8.1.2	Motor Control Centers	X	X
8.1.3	Low-Voltage Switchgear	X	X
8.1.4	Medium-Voltage Switchgear	X	X
8.1.5	Distribution Panels	X	X
8.1.6	Transformers	X	X
8.1.7	Battery Chargers and Inverters	X	X
8.1.8	Instrumentation and Control Panels	X	
8.1.9	Instruments on Racks	X	X
8.1.10	Temperature Sensors	X	
8.2.1	Fluid-Operated / Air-Operated Valves	X	X
8.2.2	Motor-Operated / Solenoid-Operated Valves	X	X
8.2.3	Horizontal Pumps	X	
8.2.4	Vertical Pumps	X	
8.2.5	Chillers	X	
8.2.6	Air Compressors	X	
8.2.7	Motor-Generators	X	
8.2.8	Engine-Generators	X	
8.2.9	Air Handlers	X	
8.2.10	Fans	X	

2.1.3.4.3 Equipment Class Evaluations Using Screening Procedures (Chapter 9)

Chapter 9 contains a summary of equipment class descriptions and parameters based on earthquake experience data, test data, and analytical derivations. The screening procedures in Chapter 9 are from Chapters 7 and 8 of Revision 2 of the SQUG GIP. An item of equipment must have the same general characteristics as the equipment in the evaluation procedures. The intent of this rule is to preclude items of equipment with unusual designs and characteristics that have not demonstrated seismic adequacy in earthquakes or tests.

The screening procedures for evaluating the seismic adequacy of the different equipment classes in Chapter 9 cover those features which experience has shown can be vulnerable to seismic loadings. These procedures are a step-by-step process through which the important equipment parameters and dimensions are determined, seismic performance concerns are evaluated, the equipment capacity is determined, and the equipment capacity is compared to the seismic demand.

The screening procedures in Chapter 9 are based on information contained in References 42, 46, 47, and 50. The SCEs should use the information in Chapter 9 only after first thoroughly reviewing and understanding the background of the equipment classes and bases for the screening procedures as described in these references. These references provide more details and more discussion than summarized in Chapter 9. In some cases, clarifying remarks not contained in the reference documents have been included in Chapter 9. These clarifying remarks are based on experience gained during SQUG GIP reviews at operating nuclear power plants and DOE seismic evaluations at DOE facilities and they serve to help guide the SCEs apply their judgment.

The screening procedures in Chapter 9 are from Revision 2 of the SQUG GIP and Table 2.1-3 lists the equipment classes in Chapter 9.

Table 2.1-3 Equipment Class Evaluations Using Screening Procedures (SQUG GIP, Reference 1)

Section	Equipment Class	Source of Screening Procedure in SQUG GIP
9.1.1	Vertical Tanks	Section 7
9.1.2	Horizontal Tanks and Heat Exchangers	Section 7
9.2.1	Cable and Conduit Raceway Systems	Section 8

2.1.3.4.4 Equipment Class Evaluations Using Screening Procedures or General Guidelines (Chapter 10)

Chapter 10 contains a summary of equipment class descriptions and parameters based on earthquake experience data, test data, and analytical derivations. The classes of equipment contained in Chapter 10 are not from the SQUG GIP. Much of the information in Chapter 10 is from DOE references. Table 2.1-4 lists the principal references and authors for the sections in Chapter 10. An item of equipment must have the same general characteristics as the equipment in the screening procedures and general guidelines. The intent of this rule is to preclude items of equipment with unusual designs and characteristics that have not demonstrated seismic adequacy in earthquakes or tests.

The screening procedures in Sections 10.1.1, 10.4.1, and 10.5.1, for evaluating the seismic adequacy of piping, HVAC ducts, and unreinforced masonry (URM) walls respectively, cover those features which experience has shown can be vulnerable to seismic loading. These procedures are a step-by-step process through which the important equipment parameters and dimensions are determined, seismic performance concerns are evaluated, the equipment capacity is determined, and the equipment capacity is compared to the seismic demand. Sections 10.1.1 and 10.4.1 have been technically reviewed and used extensively at several DOE sites including Savannah River Site and Rocky Flats Environmental Technology Center.

The general guidelines for evaluating the seismic adequacy of the equipment classes in the other sections of Chapter 10 cover those features which experience has shown can be vulnerable to seismic loading. The sections contain practical guidelines and reference to documents that can be used to implement an equipment strengthening and upgrading program. The relatively simple seismic upgrades are designed to provide cost-effective methods of enhancing the seismic safety of the equipment classes in Chapter 10. Sections 10.3.1 and 10.1.2 summarize information from portions of a DOE document that has undergone extensive technical review. Sections 10.2.1, 10.2.2, 10.2.3, 10.3.2, 10.5.2, and 10.5.3, on the other hand, are based on walkdown and seismic strengthening efforts at several DOE sites including Los Alamos National Laboratory and Lawrence Livermore National Laboratory.

Table 2.1-4 Equipment Class Evaluations Using Screening Procedures or General Guidelines

Section	Equipment Class	Principal Reference	Principal Author
10.1.1	Piping	59	G. Antaki, SRS
10.1.2	Underground Piping	29	S. Short, EQE
10.2.1	HEPA Filters		L. Goen, LANL
10.2.2	Glove Boxes		L. Goen, LANL
10.2.3	Miscellaneous Machinery	60	S. Sommer, LLNL
10.3.1	Underground Tanks	29	S. Short, EQE
10.3.2	Canisters and Gas Cylinders	60	R. Murray, LLNL
10.4.1	HVAC Ducts	28	G. Driesen, SRS
10.5.1	Unreinforced Masonry (URM) Walls		R. Murray, LLNL
10.5.2	Raised Floors	60	S. Sommer, LLNL
10.5.3	Storage Racks	60	S. Sommer, LLNL

2.1.4 Outlier Identification and Resolution[10]

Items listed in the SEL that do not pass the screening criteria contained in the Seismic Evaluation Procedure are considered outliers (i.e., they lay outside the cope of coverage for the screening criteria) and should be evaluated further as described in Chapter 12. An outlier may be shown to be adequate for seismic loads by performing evaluations such as the seismic qualification techniques currently being used in some DOE facilities. These additional evaluations and alternate methods should be thoroughly documented to permit independent review.

Methods of outlier resolution are typically more time consuming and expensive than the screening evaluations provided in the Seismic Evaluation Procedure. Also, outlier resolution may be somewhat open-ended because several different options or approaches are available to evaluate seismic adequacy. The most appropriate method of outlier resolution will depend upon a number of factors such as: (1) which of the screening criteria could not be met and by how much, (2) whether the discrepancy lends itself to an analytical evaluation, (3) how extensive the problem is in the facility and in other facilities, or (4) how difficult and expensive it would be to modify, test, or replace the subject items of equipment.

10 Based on Section 1.3.4 of SQUG GIP (Ref. 1)

2.1.5 Documentation

The suggested types of document which should be used with the DOE Seismic Evaluation Procedure are described in Chapter 13. The five major types of documents are:

- Seismic Equipment List (SEL)
- Screening Evaluation Work Sheets (SEWS)
- Outlier Seismic Evaluation Sheets (OSES)
- Screening Evaluation and Data Sheets (SEDS)
- Equipment Seismic Evaluation Report (ESER)

These documents serve as tools to summarize the results of the Screening Evaluation and Walkdown and to highlight areas in need of further evaluation or upgrading. Other, informal documentation may be used by the SCEs as an aid and these may include calculations, sketches, photographs, audio tapes, and videotapes. The completed OSES, SEWS, SEDS, and ESER constitute the documentation of the Screening Evaluation and Walkdown and reflect the final judgment of the SCEs.

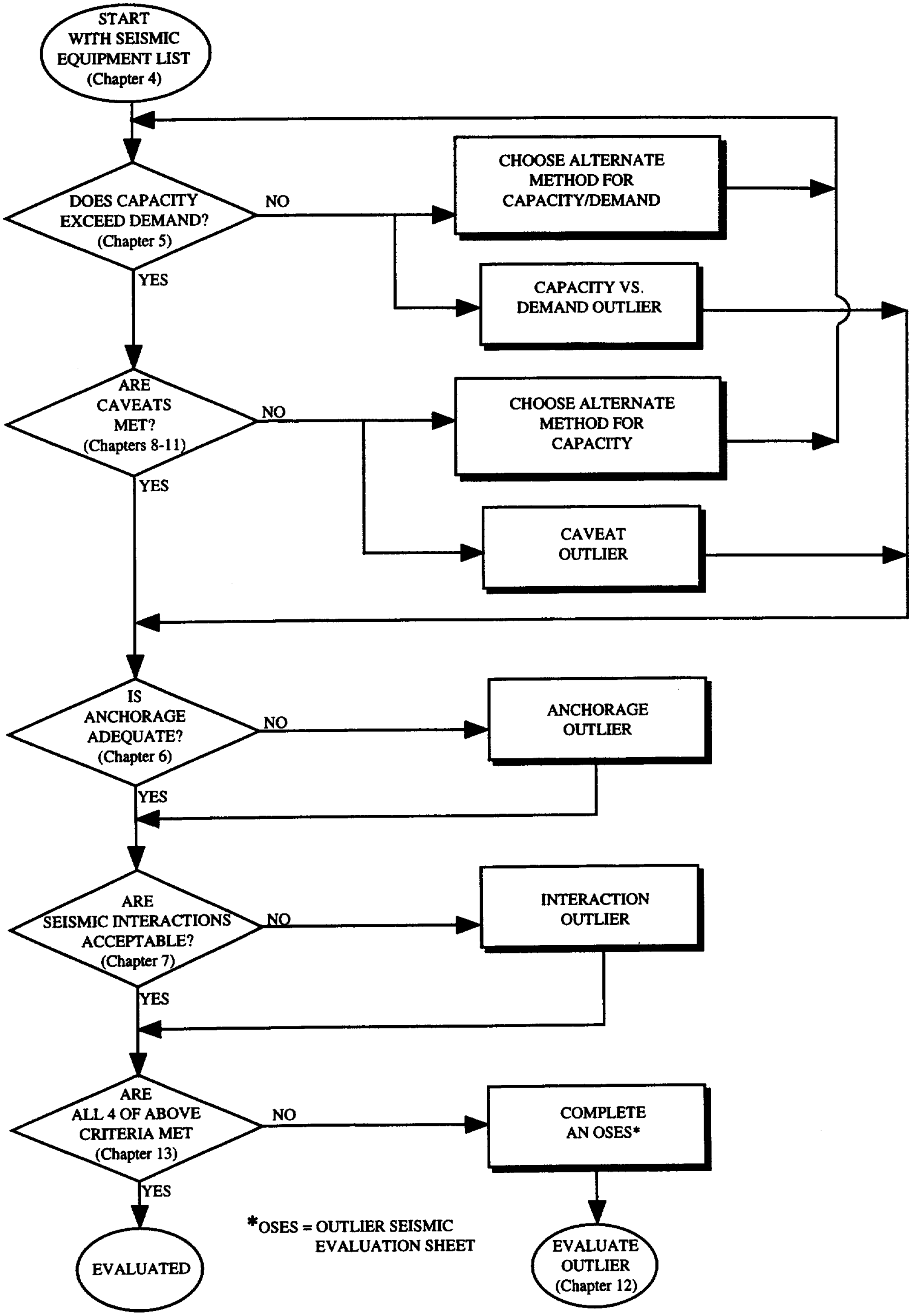

Figure 2.1-1 Overall Procedure for Performing Screening Evaluation and Walkdown (Figure 4-1 of SQUG GIP, Reference 1)

2.2 PEER REVIEW

Peer review is a vitally important component of seismic evaluations of equipment and distribution systems at DOE facilities. The evaluation procedures described in the DOE Seismic Evaluation Procedure involve an extensive use of engineering judgment. This type of judgment must be independently reviewed to ensure that significant details are not overlooked or improperly evaluated. In addition, DOE Orders and Standards discuss that peer review is a necessary element of design and evaluation for natural phenomena hazards. Peer review can be provided by certified SCEs who are independent of the SRT whose evaluation is being reviewed.

Members of a peer review team should be selected and incorporated early in the evaluation process. With review occurring in parallel with evaluations, the peer review team can efficiently study the important facets of the evaluation and provide useful feedback. The peer review team should consist of engineers that have extensive experience with seismic design and evaluation as well as be knowledgeable of the methodology and procedures in the DOE Seismic Evaluation Procedure. Typically, the members of the peer review should be more qualified than the SCEs conducting the equipment evaluations and the members should have conducted many evaluations similar to the ones being reviewed. The size of the peer review team should reflect the scope of the equipment evaluations being reviewed.

The equipment evaluations and the peer review should consider the DOE requirements for quality assurance. These requirements are specified in 10CFR830.120, the DOE Nuclear Safety Management Rule, (Ref. 61) and DOE Order 5700.6C, "Quality Assurance", (Ref. 62). The Rule requires the development of quality assurance programs for DOE nuclear facilities. Information for implementing quality procedures is provided in the Rule and Order. Sections 1.4 and C.8 of DOE-STD-1020 (Ref. 6) provides additional guidance on quality assurance and peer review.

2.3 PREPARATION FOR THE EVALUATION

2.3.1 Systems Engineering and Facility Operations[11]

Experience from facility reviews has demonstrated that preparatory work performed prior to conducting the facility screening evaluations will maximize the effectiveness of the walkdown procedure outlined in Section 2.1. Prior to the walkdown, members of the SRT including the SCEs, systems engineer(s), and facility operations representative(s) should review the facility design documents to familiarize themselves with facility design features and, in particular, those associated with equipment identified in the Seismic Equipment List (SEL). Much of the required initial information is contained in a Safety Analysis Report (SAR) or related report. In addition, piping and instrumentation diagrams (P&IDs), electrical one-line drawings, instrument block diagrams, operating procedures, system descriptions, facility arrangement drawings, and selected topical reports and specifications should be used during the equipment identification and walkdown efforts.

Discussions with facility operations personnel are beneficial in identifying equipment within various safety systems. Systems engineers may wish to consider including equipment that does not have seismic qualification documentation, thereby upgrading its seismic qualification status. Most of the industrial-grade equipment in the earthquake experience data base has been shown to be seismically rugged even though it has not been qualified for seismic loads.

Facility arrangement drawings should be marked with the location of each item of equipment selected for review and provided to the SCEs who will be doing the seismic evaluation. In

[11] Based on Sections E.1 and E.2 of SQUG GIP (Ref. 1)

addition, the SEL, which is described in Chapter 4, should be completed in order to identify the equipment to be seismically evaluated.

2.3.2 Pre-Walkdown Planning[12]

The purpose of pre-walkdown planning is to organize the facility walkdown. Judicious planning will minimize the time spent in the field by the SRT.

The planning process should be performed with active participation from the principal walkdown participants and the facility personnel with experience in the configuration and operation of the facility under review. The following organizations or individuals will typically be involved in the walkdown and should be part of the planning effort:

- Facility Manager
- Safety Professionals and Systems Engineer(s)
- Facility Operations and/or Radiation Protection Personnel
- Seismic Capability Engineers
- Relay Evaluation Personnel
- Piping Evaluation Engineers

Advance planning on when to perform the walkdown is advisable. Walkdowns should not interfere with the normal operation of the facility. Security, radiation level, operations, and maintenance considerations are necessary in deciding when each area of the facility can be visited. Some areas of the facility are inaccessible during normal operation and can only be inspected during outage periods. The Screening Evaluation and Data Sheets (SEDS), discussed in Chapter 13, can be organized by facility location and thereby used as a checklist and itinerary for the walkdown. The itinerary, however, should be flexible to allow the walkdown teams time to revisit certain areas or alter their plans because of difficulties in determining seismic adequacy of particular types of equipment. It is also advisable to provide the walkdown teams with the itineraries in advance so that they can review the items of equipment assigned prior to the walkdown.

Advance planning and preparation are needed to gain access to operating facilities, particularly if contractors are used to conduct the walkdown. The SRT may be required to obtain security clearances, access badges, and radiation training. The walkdown participants may need to be accompanied by facility security and radiation protection personnel; however, such accompaniment is costly, ties up personnel, and tends to interfere with normal facility operations and maintenance. It also increases the number of individuals involved with the walkdown which tends to slow down the pace of the effort. Advance notification and scheduling can streamline the process of gaining facility access. All people concerned with the facility walkdown, including walkdown team members, facility operations personnel, health physics personnel, security personnel and facility staff, should be advised of the dates and duration of the facility walkdown well in advance of the scheduled walkdowns (e.g., two months ahead of time).

The SRT or individual team members may want to have discussions with other facility operations personnel prior to and during the walkdown to clarify the way a system or an item of equipment operates. If possible, these meetings should be planned well in advance so that people

12 Based on Section E.3 of SQUG GIP (Ref. 1)

knowledgeable in the specific areas of concern will be available with a minimum of disruption in the normal operation of the facility.

A summary of all the available seismic design and qualification data should be prepared and provided to the SRT several weeks before their scheduled walkdown. The summary does not have to be formal, but it should be comprehensive. The SCEs performing the walkdown should become thoroughly familiar with the facility seismic design basis. The greater the understanding of the facility seismic design basis and the approaches taken for equipment qualification and anchorage, the easier it will be to exercise judgment and experience to eliminate outliers.

Construction details of the anchorage for the equipment in the SEL are essential for evaluating the seismic adequacy of the equipment. Inspection and evaluation of anchorage are difficult if not impossible without the use of construction drawings, specifications, and bills of materials.

The documents which should be available to the SRT include:

1. The Seismic Equipment List (SEL), prepared using Chapter 4.

2. List of equipment for which prior seismic qualification documentation exists.

3. Summary of the facility seismic design basis, specifically: ground response spectra for the design basis earthquake (DBE) seismic design criteria, amplified in-structure response spectra (IRS), and seismic demand spectra (SDS).

4. Standard details for equipment anchorage.

5. Facility arrangement drawings.

6. Health physics and facility security requirements.

In addition, certain facility design information should be collected to help maximize the benefit of the evaluation. The following provides a checklist of example data that, if appropriate, should be collected prior to the Screening Evaluation and Walkdown procedure:

- Map of site with outline of structures and structure identifiers
- Performance goals for the facility equipment which is listed on the SEL
- Structural drawings for buildings, including current as-built key plans where possible
- Date of construction of facility (including dates of modifications as appropriate)
- Available soils data
- General description of processes housed in the building
- Safety Analysis Reports (SARs)
- Emergency response procedures related to seismic
- Facility procedural requirements including security access

2.3.3 Screening Walkdown Plan[13]

This section describes an approach that can be used to perform the screening evaluation of the equipment listed in the SEL during the facility walkdown. This approach is based on the experience gained in performing facility reviews. This section covers the organization and approach which can be used by the SRT, the degree of inspection to be performed, walkdown logistics, and screening walkdown completion.

2.3.3.1 Organization and Approach of SRT[14]

The number of individuals in each SRT should be limited to permit ready access to inspect equipment and facilitate movement. In addition to the two SCEs, a systems or operations engineer may also be involved in the walkdown as needed by the SRT to provide information on how a system or an item of equipment operates. Health physics and security personnel may also accompany the SRT as the need arises.

Each group of individuals walking down the facility should collectively have:

1. An understanding of the facility layout and location of the various system and equipment scheduled to be evaluated during that walkdown period;
2. An understanding of the scope and objectives of the walkdown including the methodology and procedures;
3. An understanding of the seismic evaluation guidelines including inspection techniques and evaluation criteria;
4. An understanding of the operational aspects of the facility and the importance of the various facility systems and equipment.

SRT decisions concerning equipment seismic adequacy should be made on the spot, if possible, and the walkdown should proceed at a pace consistent with this objective. Decisions to evaluate the seismic adequacy of equipment should be unanimous among the SCEs. Concerns which do not permit seismic evaluation during the screening walkdown should be documented and left for further review to either eliminate the equipment as a required part of the SEL or identify it as an outlier for further evaluation (as described in Chapter 12). During the walkdown, many items of equipment may have evaluation results that are unknown. The SRT should decide what information or additional action is required to resolve the issue and inform the appropriate support staff personnel so that, if possible, the issue may be resolved during the later part of the walkdown.

If several SRTs are used to conduct the screening evaluation and walkdown, then a means for coordinating the activities should be invoked to ensure that all the equipment and activities of the evaluation are covered. This coordinating function could be performed by a single individual or by a committee of individuals from the various SRTs.

2.3.3.2 Degree of Inspection[15]

All of the equipment on the SEL should be reviewed. Exceptions to this may occur (e.g., equipment in very high radiation areas or otherwise inaccessible locations), and each exception

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[13] Based on Section F.1 of SQUG GIP (Ref. 1)
[14] Based on Section F.2 of SQUG GIP (Ref. 1)
[15] Based on Section F.3 of SQUG GIP (Ref. 1)

should be justified by the SRT. The level or scope of evaluation may vary depending upon the experience and judgment of the SRT.

2.3.3.3 Walkdown Logistics and Cautions[16]

A three-to-four hour kick-off meeting can be scheduled for the beginning of the facility walkdown. This meeting can provide a briefing on the objectives of the walkdown, the organization of the walkdown groups, the planning for the walkdown, and the breakdown of the total list of equipment for which each group was responsible. After this kick-off meeting, the SRTs can commence with the facility walkdown.

Radiation training, including whole body counts and issuance of personnel dosimetry, and facility access requirements, such as obtaining security badges, for the SRT members are done prior to this kick-off meeting. Access to contaminated and radiological areas may require DOE or site-specific Radiological Worker II Training. DOE-sponsored radiological training may reduce delays associated with facility-specific training.

A daily morning meeting should be held in which the SRT reviews the equipment included in that day's walkdown. Anchorage drawings are also reviewed by the SRT. The walkdown can be conducted in morning and afternoon sessions. A meeting can also be held during the lunch break to discuss problem areas and the approaches used by other SRTs. At the option of the facility and the SRTs, it may be desirable to conduct the walkdown outside of normal working hours. In any case, it is not recommended that the walkdown "day" exceed 10 hours.

A short meeting can also be held at the end of each day to discuss the day's walkdown, request information as required from the appropriate support staff personnel, certify the completed documentation, review information retrieved by the support staff so that previously started evaluations could be completed, and organize the next day's activities. Any unknowns are reconciled as soon as possible after the item of equipment had been inspected.

When performing the walkdown, the SRT should have the appropriate tools to collect and record data. These tools included a clip board (e.g., for SEDS and SEWS), a tape measure capable of measuring to 1/16 inch, pencils or pens, and a flashlight. The SRT may wish to use some form of carrying pack to allow hands to be free for climbing ladders, going through crawl spaces.

Other tools may be included depending on the preference of the SRT. For example, a compact camera (subject to facility policy) can be useful to record visual findings, such as each picture frame should have a designation and be fully described. A small audio cassette recorder can be used to record the subject of each picture frame and general notes about the walkdown. More elaborate visual records can be obtained by using a video recorder. However, video equipment is usually cumbersome and expensive, and has not been used extensively in past facility walkdowns. It should also be understood that the use of personal equipment is typically at the individual's own risk. If equipment is contaminated or broken, there is often no compensation by the facility.

The SRT should be aware that there is usually a need for hard hats, safety glasses, hearing protection, and sometimes safety shoes. SRT members should consider wearing light cotton clothing since temperatures inside operating DOE facilities can be relatively high. These conditions can lead to extreme personnel discomfort, especially when protective clothing is required for walkdowns in contaminated and high radiation areas.

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16 Based on Section F.4 of SQUG GIP (Ref. 1)

During the walkdown, the SRT should use caution when evaluating equipment due to the many potential dangers. Manufacturer's data should be consulted if there are any questions and/or concerns about the operation of the equipment being evaluated.

- Temporarily inactive mechanical and electrical equipment may activate while being evaluated so all manufacturer's warnings should be carefully followed.

- A common rule for evaluating equipment, especially electrical equipment, is to not break the vertical plane. Since electrical equipment may be energized, only trained personnel should provide access to this type of equipment. It is not appropriate, potentially very dangerous, and usually prohibited by facility policy to open panels on electrical equipment without approval from the appropriate facility personnel.

- Since mechanical and electrical equipment may contain vibration sensitive components, it is inappropriate to test the dynamic characteristics of the equipment by shaking it. If facility personnel indicate that the equipment does not contain vibration sensitive equipment, such as essential relays, then any field testing of the dynamic characteristics should be done within manufacturer recommendations.

- In addition, all placards with hazards control information should be reviewed, understood, and obeyed. The typical information on a hazardous material card (see Figure 2.3-1) includes level of fire hazard, level of health hazard, level of oxidation or reactivity hazard, and special information. If the information or indications on a warning label are not understood, then the appropriate facility personnel, such as hazardous material technicians or fire protection personnel, should be contacted before proceeding.

The basic rules while conducting the walkdown are to use common sense, to avoid dangerous or unpredictable situations, and to obey facility policy and safety procedures.

2.3.3.4 Screening Walkdown Completion[17]

At the completion of the Screening Evaluation and Walkdown, all equipment identified in the SEL and included in the walkdown should be classified as being either evaluated or an outlier. The SEDS should be completed, checked for accuracy, and certified for each item of equipment. The outlier sheets (OSES) should be completed for each item of equipment identified as an outlier. Work sheets (SEWS), if used, should also be checked so that the information noted (judgments, description, and calculations) can be reasonably followed by a reviewer. At the completion of the Screening Evaluation and Walkdown, the SRT should inform the facility management about the walkdown results in detail.

[17] Based on Section F.5 of SQUG GIP (Ref. 1)

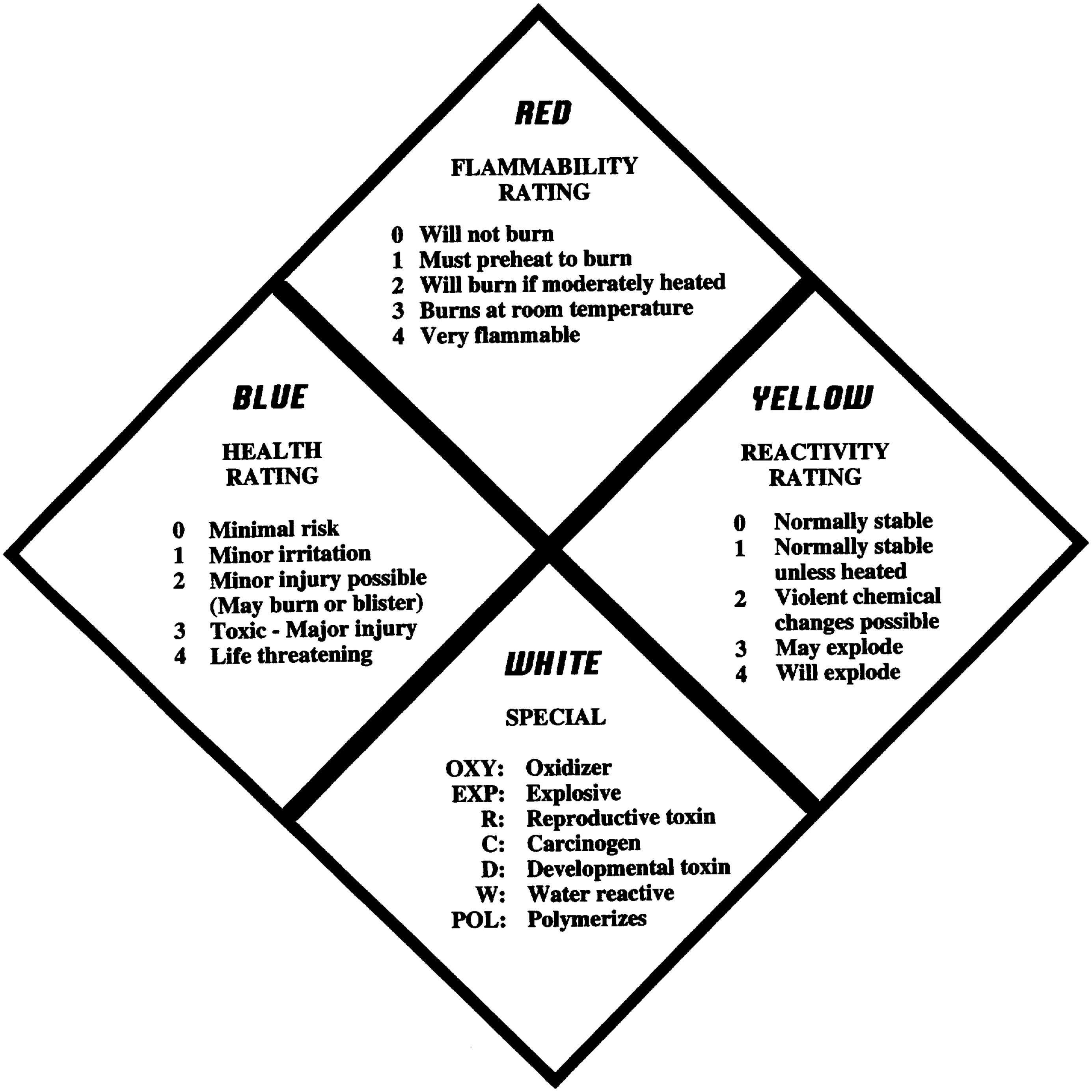

Figure 2.3-1 Hazardous Material Card

3. SEISMIC EVALUATION PERSONNEL

3.1 INTRODUCTION[1]

The purpose of this section is to define the responsibilities and recommended minimum requirements of the individuals who will implement the DOE Seismic Evaluation Procedure. The seismic evaluation personnel include individuals who develop the Seismic Equipment List (SEL), perform the facility walkdown and evaluate the seismic adequacy of equipment listed in the SEL, and perform the relay screening and evaluation. This may involve a number of safety, facility, and engineering disciplines including structural, mechanical, civil, electrical, systems, and seismic.

Most facilities may prefer to implement this procedure using a designated team of individuals; i.e., a Seismic Review Team (SRT). However, the functions and responsibilities may be assigned to existing departments or groups, without definition of a dedicated team, provided the individuals in these departments or groups have the appropriate qualifications and training and that the walkdown teams have the required collective qualifications. Similarly, the individuals who undertake the seismic review may be DOE staff; M&O contractor staff; and subcontractors, who are currently under contract to DOE or a M&O, provided the qualification and training criteria are met. This flexibility allows for the possibility that the functions may be performed by individuals of different disciplines at different times. DOE and M&O contractor staff are responsible for evaluating the qualifications of the seismic evaluation personnel for compliance with this procedure.

3.2 SEISMIC CAPABILITY ENGINEERS[2]

3.2.1 Responsibilities and Minimum Requirements

The Seismic Capability Engineers (SCEs) should:

- Become familiar with the seismic experience data approach as defined in the DOE Seismic Evaluation Procedure and EPRI / SQUG reference documents.

- Become familiar with the seismic design basis of the facility being evaluated, especially the equipment on the SEL and the Design Basis Earthquake (DBE) for the facility.

- Conduct the seismic evaluations and walkdowns of equipment and systems as described in the following chapters and sections:

    - Capacity versus Demand Evaluation (Chapter 5)

    - Anchorage Review (Chapter 6)

    - Seismic Interaction Evaluation (Chapter 7)

    - Equipment Class Evaluations Using Caveats for the Reference Spectrum and/or GERS (Chapter 8)

    - Equipment Class Evaluations Using Screening Procedures (Chapter 9)

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[1] Based on Section 2.0 of SQUG GIP (Ref. 1)
[2] Based on Section 2.4 of SQUG GIP (Ref. 1)

- Equipment Class Evaluations Using Screening Procedures or General Guidelines (Chapter 10)

- Relay Functionality Review (Chapter 11)

- Use the DOE Seismic Evaluation Procedure, along with experience and judgment, to evaluate the seismic adequacy of equipment and systems identified as necessary.

- Perform additional analyses and calculations, when necessary, to evaluate the seismic adequacy of the equipment and systems.

- Make recommendations for any additional evaluations or physical modifications to equipment or systems that may be necessary to determine the seismic adequacy of equipment identified as outliers as described in Chapter 12.

The SCEs may be assisted in fulfilling the above responsibilities by other individuals. For example, others may do background work to obtain information necessary for performing the seismic evaluations; they may also locate and assist in evaluating existing seismic qualification documentation; and they may perform backup calculations where necessary. Another example is that SCEs may ask the Systems Engineers, Safety Professionals, and the Operations Personnel for information on how an item of equipment operates in a system so they may decide whether a malfunction of certain features of the item of equipment will affect its safety performance. Regardless of what help the SCEs receive from others, they should remain fully responsible for all the seismic evaluations, engineering judgments, and documentation, including the details and backup documentation.

The recommended minimum requirements for the SCEs are:

- Bachelor of Science degree, or equivalent, in structural, mechanical, or civil engineering or related discipline,

- 5 years of experience in seismic design, testing, analysis, and/or evaluation of structures and equipment in DOE facilities and / or commercial nuclear power plants,

- Complete the 5-day DOE-developed training course on applying the EPRI / SQUG walkdown screening and seismic evaluation methodology for equipment at DOE facilities.

If an engineer has completed the 5-day EPRI training course on the EPRI / SQUG methodology for the commercial nuclear power industry, then the following list provides an alternative means of meeting the recommended minimum requirements for SCEs evaluating equipment at DOE facilities. The list replaces the recommended minimum requirement of attending the 5-day DOE-developed training course.

- Hold a certificate of completion for the 5-day EPRI course on the SQUG methodology presented for the commercial nuclear power industry,

- Complete the following supplemental DOE-specific training administrated under the oversight of the DOE: performance goals, capacity versus demand, and equipment classes beyond those covered in the EPRI course, as well as complete the associated case studies and quizzes. This supplemental training is conducted on a case-by-case basis depending on the qualifications of the engineer. It typically does not involve attendance of another training course.

The Screening Evaluation and Walkdown should be conducted by one or more SRTs consisting of at least two SCEs on each team. The engineers on each team should collectively possess the following knowledge and experience:

- Experience in seismic design, seismic analysis and test qualification practices at DOE facilities. This should include active mechanical and electrical equipment, process and control equipment, and safety equipment.

- Knowledge of the performance of equipment, systems, and structures during strong motion earthquakes in industrial process and power plants. This should include active mechanical and electrical equipment, process and control equipment, and safety equipment.

- DOE facility walkdown experience.

- Knowledge of DOE orders, standards, and guidance.

It is not necessary for each SCE to possess all of the above qualifications; differing levels of expertise among the SRT engineers is appropriate. However, each SRT should collectively possess the above qualifications and each engineer on the team should have the ability to make judgments regarding the seismic adequacy of equipment.

At least one of the SCEs on each of the SRTs should be a licensed Professional Engineer to ensure that there is a measure of accountability and personal responsibility in making the judgments called for in the DOE Seismic Evaluation Procedure.

In general, the individuals who perform the seismic review walkdown may be required to wear protective clothing, wear a respirator, work in radiation areas, climb ladders, move through crawl spaces, climb over obstacles, and work in high temperatures or other difficult situations. In addition to required facility-specific training, the SRT members should be in good physical condition and have the capability and willingness to perform these tasks as necessary.

3.2.2 Piping Evaluation Engineers

The Piping Evaluation Engineers are responsible for conducting the walkdown and screening verification of piping that is listed in the SEL. Recommended minimum requirements for the Piping Evaluation Engineers are:

- Satisfy recommended minimum requirements for SCEs,

- 5 years of experience in seismic design and / or evaluation of piping systems and support structures is desirable with the capability to apply sound engineering judgment based on the knowledge of the behavior of piping systems in actual earthquakes and seismic tests and to recognize potential failure modes,

- Complete the 1-day DOE-developed workshop, or equivalent, on applying the walkdown screening and seismic evaluation methodology for piping at DOE facilities.

3.3 OTHER SUPPORT PERSONNEL

There are several other groups of personnel who provide important assistance to the SCEs. These personnel include safety professional and systems engineers, operations personnel, and relay evaluation personnel. The combination of these personnel and the SCEs comprise a complete SRT.

3.3.1 Safety Professionals and Systems Engineers[3]

The primary responsibility of the Safety Professionals and Systems Engineers is to develop the SEL, as described in Chapter 4. This involves identifying the various types of safety equipment that exist within the facility and determining which types will be evaluated with the Screening Evaluation and Walkdown.

If the SEL contains few outliers following the facility walkdown, further evaluation by the Safety Professionals and Systems Engineers may not be necessary. However, if as a result of the walkdown, numerous outliers are found or outliers which are difficult to resolve are identified, the Safety Professionals and Systems Engineers may be requested to further evaluate the SEL.

In addition to the primary responsibility of developing the SEL, the Safety Professionals and Systems Engineers may be asked to provide background information and guidance to the SCEs who evaluate the seismic adequacy of the equipment and the Relay Evaluation Professionals who perform the relay functionality review.

The Safety Professionals and Systems Engineers should be degreed engineers, or equivalent, and have extensive experience with the broad understanding of the systems, equipment, and procedures of the DOE facility being evaluated.

3.3.2 Operations Personnel[4]

The Operations Personnel have two types of responsibilities during implementation of this procedure. First, they are responsible for reviewing the SEL (developed in Chapter 4) to confirm that the SEL is compatible with approved normal and emergency operating procedures for the facility. Second, Operations Personnel may be asked to assist the SCEs during the Screening Evaluation and Walkdown and assist the Relay Review Personnel during the Relay Functionality Review.

To fulfill these responsibilities, the Operations Personnel should have knowledge of both steady-state and transient operations and the associated facility-specific operating procedures. They should be able to supply information on the consequences of, and operator recovery from, functional anomalies. It is their responsibility to provide information on the function and operation of individual equipment, instrumentation, and control systems.

Operations Personnel may assist the SCEs either as staff support or as members of an SRT. Though it is not required that the Operations Personnel be part of the seismic walkdown team, it is recommended. The Operations Personnel should have experience in the specific facility being seismically evaluated.

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[3] Based on Section 2.2 of SQUG GIP (Ref. 1)

[4] Based on Section 2.3 of SQUG GIP (Ref. 1)

3.3.3 Relay Evaluation Personnel[5]

The Relay Evaluation Personnel include those individuals who will perform the Relay Functionality Review described in Chapter 11. This evaluation includes reviewing electrical circuit drawings, documenting the review conclusions, performing the relay walkdowns, and providing associated support activities.

Electrical engineering will be the primary engineering discipline involved in the relay review; however, the evaluation may also use a number of other engineering disciplines; including structural, mechanical, civil, systems, and earthquake engineering. Information and assistance from facility personnel regarding operations and maintenance may also be required. The capabilities and responsibilities of the various Relay Evaluation Personnel are listed below.

The Lead Relay Reviewer should be a degreed, or equivalent, electrical engineer with experience who is familiar with the Relay Functionality Review procedure described Chapter 11. The relay walkdown is not expected to involve entries into radiation areas nor any special physical demands. The Lead Relay Reviewer should either perform the review or assist reviewers in interpreting electrical design drawings and in identifying essential relays in the safety systems. The Lead Relay Reviewer should have a good understanding of circuit design logic and the consequences of relay malfunction in essential circuits.

Assistant Relay Reviewers with electrical engineering, or equivalent, backgrounds can be used to document the relay review and obtain support documentation such as electrical drawings, technical specifications, operator reference manuals, and procedures

Safety Professionals, Systems Engineers and Operations Personnel who are capable of providing information on the operation of the safety systems and facility operating procedures should be used in the Relay Functionality Review. Their assistance will be needed to identify equipment for the SEL and essential control and power circuits which may be tripped as a result of an earthquake. They should also be able to provide information on the instrumentation and controls available to monitor and control the equipment affected by relays. A staff electrical and/or instrumentation and controls maintenance representative should be available to provide assistance during the Relay Functionality Review to help establish the location, mounting, types and characteristics of relays in the safety circuits.

The SCEs should perform certain appropriate evaluations in support of the Relay Functionality Review. These evaluations can be performed during the Screening Evaluation and Walkdown and include:

- Identifying potential instances of seismic spatial interaction.
- Giving special consideration to expansion anchor bolts which secure cabinets containing essential relays.
- Establishing in-cabinet amplification factors for and lowest natural frequency of cabinets containing essential relays.

[5] Based on Section 2.5 of SQUG GIP (Ref. 1)

3.4 TRAINING

A workshop and training course were developed by DOE to provide guidance on how to implement seismic evaluations using the DOE Seismic Evaluation Procedure and the referenced EPRI / SQUG documents.

DOE Workshop on Walkdown Field Guide and SQUG / EPRI Seismic Qualification Material (Reference 63) The workshop provides an overview of the methodology employed by the EPRI / SQUG seismic qualification material for seismic evaluations of equipment in existing DOE facilities. By attending the workshop, participants obtain copies of the EPRI / SQUG evaluation material for use at DOE facilities. The workshop is provided for DOE staff, M&O contractor staff, and subcontractors who were under contract to DOE or a M&O. In addition, the workshop had training on the use of the Walkthrough Field Guide which is discussed in Section 1.4.1. The intent of the Field Guide training is to introduce techniques for efficiently identifying and upgrading significant seismic concerns at DOE facilities.

DOE Training Course on SQUG / EPRI Walkdown Screening and Seismic Evaluation Material (Reference 64) The training course provides guidance for implementing and following the procedures of the DOE Seismic Evaluation Procedure. Detailed information about the Screening Evaluation and Walkdown Procedure, capacity versus demand evaluation, anchorage review, seismic interaction evaluation, electrical and mechanical equipment review, tanks and heat exchangers review, cable tray and conduit systems review, and relay functionality review is presented in the course. As part of the course, attendees complete a study guide and pre-test, complete quizzes, and participate in a walkdown. This course is provided primarily for the SCEs, however others who may support these engineers may also take this course. Attendance at the training course is currently a mandatory step for any DOE site to obtain the EPRI / SQUG documents and to permit use of the documents for safety-basis evaluations. Videotapes of the course are available through LLNL.

The objective of the DOE training course is as follows: (1) provide additional information on the background, philosophy, and general approach developed by the DOE to conduct seismic evaluations of DOE facilities and (2) provide additional guidance in the use of the DOE Seismic Evaluation Procedure and applicable references to select the SEL and to verify their seismic adequacy. Implementation of the procedures in the DOE Seismic Evaluation Procedure require experienced, well-trained engineers applying sound engineering judgment. As a result, the training course provides for the transfer of the necessary technology to DOE sites and the training of DOE and contractor personnel to conduct seismic evaluations.

A revised version of the training course in Reference 64 provides tailored training for DOE sites. This revised version emphasizes the DOE Seismic Evaluation Procedure and the aspects of the Procedure which are of most interest to DOE sites. In addition to the material discussed in Reference 64, the revised training covers DOE-specific classes of equipment, such as piping, HVAC ducts, and architectural features and components.

DOE Workshop on Qualification of Piping Systems (Reference 65) The workshop provides guidance for implementing and following the procedures of the DOE Seismic Evaluation Procedure for piping systems. Detailed information about the codes and standards for process, instrumentation, and fire protection piping systems; loading of piping systems; qualification by analysis; testing experience data; earthquake experience data; seismic screening criteria for piping and tubing; special considerations for buried piping; and special considerations for double-wall piping are presented at the workshop. As part of the workshop, attendees participate in discussions and are given an examination. This workshop is provided primarily for SCEs who are also Piping Evaluation Engineers, however others who may support these engineers should also take this course.

4. SEISMIC EQUIPMENT LIST

4.1 GENERAL APPROACH

The methodology and procedures for evaluating the seismic adequacy of systems and components described in the DOE Seismic Evaluation Procedure are based on the observed performance, failure, and response of various types of systems and components during and after actual earthquake motion or simulated earthquake motion on a shake table. Systems and components can be evaluated for seismic adequacy using the methods and procedures in the DOE Seismic Evaluation Procedure provided that the associated guidelines, limitations, requirements, and caveats described in the procedure are satisfied. This chapter provides guidelines and some discussion to aid in preparing a list of systems and components that can be seismically evaluated to meet the intent of DOE Orders and standards. A prescriptive method for developing the Seismic Equipment List (SEL) is not provided in this chapter because each DOE facility may utilize methods which address facility-specific issues. Even though the SEL is intended for all systems and components, it will primarily consist of systems and components which, if damaged or destroyed, could potentially harm the environment, public and/or workers.

DOE Orders and standards on natural phenomena hazards require that all systems and components be seismically evaluated, except for Performance Category (PC)-0 systems and components. All PC-1 through PC-4 systems and components could then be included in the SEL of the facility. However, the DOE Orders and standards use a "graded approach" permitting the level of rigor and thoroughness of seismic adequacy evaluation to vary in proportion to the importance and significance of the systems and components being evaluated. Consistent with this approach and recognizing the impracticality of performing seismic evaluation and upgrading of all DOE facilities simultaneously, DOE Orders and standards permit prioritization of seismic evaluation and upgrading of various systems and components on some rational basis, such as the risk reduction potential associated with the seismic evaluation and upgrading of a particular system or component. DOE Orders and standards also permit some relaxation of the requirements for older-vintage and existing facilities consistent with a backfit principle. The use of the screening methods and procedures described in the DOE Seismic Evaluation Procedure is based on similar principles.

The above-mentioned relaxation and prioritization provisions of DOE Orders and standards permit an SEL that is not all inclusive, even though all PC-1 through PC-4 systems and components could be in the SEL. Considering the availability of resources and the estimated risk-reduction potential, it is acceptable for only certain systems and components to be included in the SEL. Since a rigorous determination of the risk reduction potential for a large number of systems and components is not practical, an approximate and subjective estimation is acceptable. With appropriate guidance from facility management on resource availability and facility mission, the estimation of relative risk-reduction potential and preparation of an SEL can best be performed by a team, the SEL Team. This team should consist of safety professionals, facility system safety engineers, seismic engineers, and facility operators. For some facilities, the SEL Team may need to incorporate the specialized expertise of relay engineers, piping engineers, chemical engineers, or other professionals and facility designers.

The general approach for the development of the SEL requires the consideration of the following items: identification of facility safety requirements, postulated facility conditions, system interaction considerations, and seismic vulnerability considerations. From these considerations, it is anticipated that a preliminary SEL can be developed. To complete the SEL it is recommended that the preliminary SEL undergo an operational review for concurrence by facility operators.

4.2 IDENTIFICATION OF FACILITY SAFETY REQUIREMENTS

As discussed earlier, the SEL will contain only a portion of the facility systems and components and, in many cases, the SEL will contain only safety-related systems and components which must function during or after a seismic event. To determine which systems and components belong in the SEL, the selection should be based on the results of accident analyses. These accident analyses should consider all the appropriate facility hazards as required by the applicable DOE Orders, such as DOE Order 420.1 (Ref. 5), DOE Order 5480.23 (Ref. 9) for nuclear facilities, DOE Order 5480.30 (Ref. 66) for nuclear reactors, DOE Order 5480.25 (Ref. 67) for accelerator facilities, and DOE Order 5481.1B (Ref. 68) for nonnuclear facilities.

Accident analyses and their results are typically provided in a Safety Analysis Report (SAR) for the DOE facility being evaluated and the SEL should be based on information provided in the SAR. For a nonreactor nuclear facility, DOE-STD-3009 (Ref. 11) provides guidance on the preparation of a SAR. Using the guidance in DOE-STD-3009 and the appropriate accident analyses in the SAR, systems and components can be differentiated into Safety Class or Safety Significant. The SEL can focus on those facility systems and components which are classified as Safety Class or Safety Significant. These systems and components are typically those which must function during or after a seismic event. For facilities without a SAR, hazard and/or accident analyses comparable to those required for a SAR should be performed to identify systems and components needed to perform safety functions.

Additional guidance for the development of the SEL is provided in DOE-STD-1021 (Ref. 7) and DOE-STD-1027 (Ref. 10). The results of facility hazard classification, safety classification, and performance categorization are considered in DOE-STD-1021. With these considerations, the facility systems and components can be assigned to the appropriate performance category. The SEL can focus on those facility systems and components which are classified above a specified performance category and these systems and components are typically those which must function during or after a seismic event.

4.3 POSTULATED FACILITY CONDITIONS

In developing the SEL, the SEL Team will need to postulate facility conditions following a seismic event. These postulated conditions will help the SEL Team to identify systems and components needed following an earthquake and serve as a basis of questions asked during the operational review.

- <u>Offsite Utilities:</u> Offsite utilities such as power, telephone, water, steam and gas supplies should be considered for two conditions:

  1) Offsite utilities are interrupted and are not available for up to 72 hours.

  2) Offsite utilities are uninterrupted.

- <u>Seismic Induced Accidents:</u> Postulate seismic induced accidents, such as fire and criticality, unless a hazard analysis is performed to show that such events are not credible.

- <u>Single Active Failure:</u> Postulate random or seismically induced failure of any single active component on the SEL.

- Operator Actions: Consider operator actions, as necessary, provided the following conditions are met:

    1) Procedures and training are in place.

    2) Procedures take into account the environment which will result from the postulated earthquake.

    3) Operator actions utilize seismically qualified components and instrument alarms.

    4) Egress routes are confirmed viable by seismic review. An alternate egress route must be included in operator action procedures, unless a single route is structurally qualified (including opening of doors and emergency lighting). In addition, access routes for the operator to activate alarms may be required.

- Other Accidents: Do not postulate that other natural phenomena hazards (extreme winds, floods) or man-made accidents (sabotage, plane-crash) occur simultaneously with the earthquake.

4.4 SYSTEM INTERACTION CONSIDERATIONS

In preparing the SEL for a facility, system safety will be the primary consideration and the safety professionals and system engineers in the SEL Team will have the primary responsibility of selecting systems and components that must be seismically evaluated. This is a primary consideration for facilities that contain, store, or process nuclear or chemically hazardous materials. For such facilities, the responsibility of the system engineers of the SEL Team will be to grade the candidate systems and components according to their safety significance in relation to the consequences of their failure during or following a seismic event. Such grading may be performed on the basis of system safety studies, if any, associated with the development of SARs and with DOE-STD-1021 (Ref. 7). In addition to the data on conventional safety classification or seismic performance categorization of systems and components, additional data on the approximate number of on-site and off-site individuals that are likely to be adversely affected and the extent of potential damage to the environment will be useful in assessing the relative safety significance of the systems and components.

The SEL Team, especially the safety professionals and system engineers, should also include the following considerations in their evaluation of safety significance of the systems and components:

- Seismic Interaction Effects: The effect of one failure of a systems or component on the performance of other safety-related systems and components should be considered.

- Common-Cause Failure Effects: Since a seismic event affects all systems and components within a facility, several non-safety related systems and components may fail and result in the unacceptable performance or failure of a safety-related systems or component. The effects of such common-cause failure on non-safety related systems and components should be considered.

- Performance During a Seismic Event: Not all safety-related systems and components need to continuously function during a seismic event to meet their safety requirement, as long as they perform their safety-related function after the event. Functional failure of such systems and components during a seismic event is obviously not significant compared to those systems and components, such as some switches and relays, which must function during the event.

4.5 SEISMIC VULNERABILITY CONSIDERATIONS

In developing the SEL, structural and seismic vulnerability considerations are also important. In general, the systems and components that are inherently or generically susceptible to seismic failure or malfunction should get more attention in the evaluation process than those that are inherently rugged. The determination and assessment of seismic weakness or ruggedness for the purpose of preparing the SEL will be the responsibility of the SEL Team, especially the seismic engineers. The seismic engineers will consider: (1) the structural configuration of the system or component in relation to its function, (2) its potential failure mode (ductile or brittle, large displacement, vibration sensitivity, unacceptable function even though stress or displacement is within acceptable limits, etc.), (3) generic performance during past earthquakes or during shake table test, and (4) the actual attachment and support conditions of the system or component.

A systematic walkthrough is recommended to evaluate the seismic ruggedness of the systems and components and their support and anchorage. The Walkthrough Screening Evaluation Field Guide (Ref. 23) discussed in Section 1.4 can aid this process. A brief review of seismic design documents and records is also necessary to assess the seismic vulnerability of the systems and components. Based on such walkthrough and document review, the seismic engineer of the SEL Team will subjectively evaluate the relative seismic vulnerability of the systems and components that are included in the SEL prepared by the safety professionals and system engineers. As a result of this seismic vulnerability evaluation, each system or component of the SEL, which was prepared on the basis of safety considerations, will have a qualitative seismic vulnerability rating which, when combined with the system safety significance, can provide an assessment of the relative risk associated with the seismic event.

4.6 OPERATIONAL REVIEW

The SEL prepared from the considerations discussed in Sections 4.2, 4.3, 4.4 and 4.5 should be reviewed by the SEL Team for operational and functional considerations. The facility operators will specially review the completeness of the list to ensure that the systems and components whose functionality and integrity are assumed essential for personnel and public safety by the operating personnel are included in the SEL. To assist the SEL Team and facility operators in reviewing the preliminary SEL, the following questions are suggested:

- What are the hazards to the public, workers, or environment upon failure of facility systems and components?
- What are the confinement systems in place to protect the public or environment from facility operations or accidents?
- What are the procedures in the event of a loss of off-site power?
- What are the facility emergency response and evacuation procedures, monitors, alarms, and routes for a major seismic event?
- Are there essential instrumentation and controls for vital components needed to provide confinement?
- What type of fire protection system does the facility have (wet systems, dry systems, any functional requirements of any pumps)?
- What type of monitoring systems and components does the facility have (continuous air monitors, high-radiation area monitors, stack monitors, and associated operational requirements)?

- What type of alarm systems does the facility have?
- What, if any, are the operational requirements for components in the confinement systems?
- Is any operator intervention required to operate the vital components for confinement?
- What success paths are available for placing any hazardous operations into a safe state including those requiring operator action?
- Upon loss of off-site power, what is the failure state of active confinement systems (e.g., will air be needed to re-open dampers)?
- Are there any highly important and expensive experiments or unique components that if lost, would jeopardize the mission of the facility due to excessive downtime?
- Are there significant common-cause interaction effects?
- What support systems do facility systems and components depend on to fulfill their safety functions?
- What defense-in-depth features are required for the facility systems and components?

Information to help answer the above questions may be in the facility SAR or other related safety documents. After addressing these questions in the operational review and revising the preliminary SEL based on the answers to the questions, the final SEL can be developed.